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ROCKWELL INTERNATIONAL
NORTH AMERICAN SPACE OPERATIONS
ROCKY FLATS PLANT

Remedial Investigation Report for High Priority Sites

(881 Hillside Area)

Volume III

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

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Section 5.0

5.0 SITE HYDROGEOLOGY

This section presents the results of hydrogeologic investigations of the 881 Hillside Area at the Rocky Flats Plant. The section begins with detailed geologic descriptions of surficial and bedrock materials with emphasis on their hydrologic properties. Geologic descriptions are followed by a discussion of ground-water flow in various materials and their interconnection. The section concludes with a narrative on the nature and extent of ground-water contamination at the 881 Hillside Area.

Hydrogeologic and geochemical interpretations are based on information gathered from 23 boreholes and 28 monitor wells completed during the 1986 and 1987 drilling programs. Plate 2-1 shows the locations of all monitor wells at Rocky Flats Plant, and Plate 5-1 presents borehole and monitor well locations at the 881 Hillside Area. Appendix A of this report contains excerpts from the RI Work Plan which pertain to this investigation, and Appendix D presents the rationale for final borehole and well locations as well as drilling and sampling procedures implemented during the RI. Hydrogeologic data collected during the remedial investigation are presented in Appendix E. This includes geologic logs of all boreholes and wells, well completion data sheets, packer test data sheets and results, slug test data and results, and water level data sheets. Appendix E contains analytical results from soil, ground-water, and surface water sampling programs. Quality assurance/quality control (QA/QC) documentation and evaluations for field and laboratory work are provided in Appendix G.

5.1 SURFICIAL GEOLOGY

Surficial materials at the 881 Hillside Area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill unconformably overlying bedrock. In addition, there are a few isolate exposures of claystone bedrock. Plate 5-1 presents the distribution of surficial materials. The study area is located on the south-facing hillside which slopes down from the Rocky Flats terrace surface toward Woman Creek on the south side of the Plant. Rocky Flats Alluvium caps the top of the slope, and colluvium (slope wash) covers the hillside. Artificial fill and disturbed surficial materials are present around Building 881 and south of the building to the South Interceptor Ditch. Artificial fill overlies colluvium at SWMU 130, and surficial materials are disturbed in the vicinity of SWMUs 119.1 and 119.2. Valley fill alluvium is present along the drainage of Woman Creek south of the 881 Hillside Area, and terrace alluvium occurs on the north side of the Woman Creek valley fill alluvium (wells 58-86 and 55-87).

5.1.1 Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at the Rocky Flats Plant; it is Nebraskan in age (Figure 3-10, Scott, 1965). The Rocky Flats Alluvium is a series of coalescing alluvial fans deposited by braided streams (Hurr, 1976). The erosional surface (pediment) on which the alluvium was deposited slopes gently eastward truncating the Fox Hills Sandstone, the Laramie Formation, and the Arapahoe Formation at the Rocky Flats Plant.

After deposition of the Rocky Flats Alluvium, eastward flowing streams began dissecting the deposit by headward erosion and lateral planation. All of the alluvium was removed by erosion in the Woman Creek drainage south of the 881 Hillside Area and in the South Walnut Creek drainage to the north. The result is a terrace of Rocky Flats Alluvium extending eastward from the Plant between the two drainages. This terrace forms the crest of the 881 Hillside Area.

The Rocky Flats Alluvium is a poorly to moderately sorted, unconsolidated deposit of clay, silt, sand, gravel, and cobbles. Colors of the alluvium vary widely from pale yellowish brown (10 YR 6/2) (GSA Rock Color Chart) to dark yellowish brown (10 YR 4/2) with various interspersed grays and browns. Occasional staining of moderate reddish brown (10 R 4/6) and dark yellowish orange (10 YR 6/6) is encountered. The grain size of the quartz and granite sand comprising the alluvium range from fine-grained (2.5Ø) to medium-grained (2.0Ø)(borehole BH7-87). Quartzite and granite gravels, pebbles, and cobbles are predominantly subangular, indicative of materials transported short distances. The Rocky Flats Alluvium north of the 881 Hillside Area is up to 19.0 feet in thickness (BH15-87).

5.1.2 Colluvium

Colluvial materials are present on the hillside below the Rocky Flats terrace east of Building 881 and extend south to the Woman Creek drainage (Plate 5-1). These materials are deposited by slope wash and downslope creep of Rocky Flats Alluvium and claystone bedrock. Colluvium ranges from two feet (BH16-87) to twenty-two feet (well 62-86) in thickness.

Colluvial materials on the 881 Hillside have been disturbed by construction of Building 881, various excavation activities associated with the SWMUs and construction of the South Interceptor Ditch. These areas are shown as disturbed ground on Plate 5-1. Within SWMUs 119.1 and 119.2, shallow excavation took place to construct roadways and to provide level drum storage areas (Plate 5-4, cross section H-H'). Colluvium is also disturbed south of Building 881 in the vicinity of SWMUs 106 and 107. This area was excavated during construction of the skimming pond in 1972 (Plate 5-2, cross section C-C'). Finally, colluvium was excavated along the South Interceptor Ditch during its construction in 1981 (Plate 5-3, cross section E-E' and Plate 5-4, cross section G-G').

Colluvium is undisturbed on the hillside south of SWMUs 130, 119.1, and 119.2. Based on Cross Section F-F' (Plate 5-4), the colluvium is thickest in the north-south trending swales draining the 881 Hillside (wells 4-87 and 6-87) and thinnest over the intervening ridges (wells 48-87, 49-87, and 50-87).

Colluvium predominantly consists of clay with common occurrences of sandy clay and gravel layers. Colluvial clay is typically poorly consolidated and ranges from moderate yellowish brown (10 YR 5/4) to dusky brown (5 YR 2/2) in color. The sandy intervals contain moderate yellowish brown (10 YR 5/4) to dark yellowish brown (10 YR 4/2) colors, and vary from very fine-grained to coarse-grained (4.0Ø to 0.0Ø), rounded to subangular quartzose sand. The sandy intervals range from poorly to well sorted and are generally poorly consolidated.

Gravel layers are also present in colluvial materials both unconformably overlying bedrock and near surface. These gravels were likely deposited in a south (downslope) direction by creep and slope wash erosion of the Rocky Flats Alluvium and can be expected to be elongate in the north-south direction and or rather limited extent in the east-west. The gravel layers range from 1.3 feet (wells 43-87, 62-86, and 69-86) to 5.5 feet (well 59-86) in thickness.

Colluvial gravel deposits can be correlated between some of the wells and boreholes. For example, the basal gravel in well 59-86 can be traced to wells 69-86 and 8-87BR (Plate 5-2, Cross Section C-C'). Sand and gravel layers in well 43-87 can also be correlated with sand and gravel layers in well 4-87 and to a clay and gravel layer in well 47-87 (Plate 5-3, Cross Section E-E'). However, the gravel layer may pinch out between the wells, based on water chemistry results.

The gravel layers are typically poorly sorted, unconsolidated granitic pebbles and cobbles with little clay and some coarse-grained to medium-grained sand. Colors range from moderate yellowish brown (10 YR 5/4) to light brown (5 YR 5/6) with brown, orange, and yellow staining. Some of the gravel layers are poorly cemented with calcium carbonate cement (caliche). The caliche is generally grayish orange (10 YR 7/4) to very pale orange (10 YR 8/2) in color.

5.1.3 Terrace Alluvium

A Quaternary terrace alluvium is present on the north side of the Woman Creek valley fill alluvium. This terrace is approximately 5 to 10 feet above the present stream level indicating that it is probably Holocene in age (Scott, 1960). The thickness of the deposit ranges from approximately three (well 58-86) to seven (well 55-87) feet, as shown on Cross Section E-E' (Plate 5-3).

The terrace alluvium is composed of very poorly sorted gravelly sand. It ranges from yellowish brown (10 YR 5/4) to moderate brown (5 YR 3/4) in color and from silty clay to small cobbles in grain size. Coarser grains are subrounded to angular.

5.1.4 Valley Fill Alluvium

The most recent alluvial deposit in the 881 Hillside Area is the valley fill alluvium along Woman Creek. This alluvium is derived from reworked and redeposited older alluviums and bedrock. Alluvium thickness ranges from approximately 6 feet (well 68-86) to 9 feet (well 64-86).

The unconsolidated valley fill alluvium consists of generally poorly sorted, angular to subrounded granite and quartzite cobbles, pebbles, and gravels in a silty sand matrix. Colors range from dusky yellowish brown (10 YR 2/2) to moderate yellowish brown (10 YR 5/4) with intervals of yellowish gray (5 Y 7/2) silty sand and greenish gray (5 GY 6/1) clay encountered in well 64-86 (Plate 5-4, Cross Section G-G').

5.1.5 Artificial Fill

There are two types of artificial fill on the 881 Hillside (Plate 5-1) derived from separate sources. The first is fill material derived from excavation of the Building 881 foundation, and the second is soil placed at SWMU 130 from the 1969 fire cleanup (Section 4.0).

Material excavated for the Building 881 foundation was spread over a large area generally south of the building. The very poorly sorted and unconsolidated artificial fill was derived from Rocky Flats Alluvium, colluvium, and claystone bedrock. It is predominantly composed of sandy clay with some gravelly zones (Plate

5-2, Cross Section A-A' and B-B'). The fill is generally brown to gray in color with occasional zones of moderate yellowish brown staining. A weakly cemented zone of caliche was encountered in well 54-87. The fill is underlain by colluvial and bedrock materials, and ranges from two to five feet in thickness.

Soils placed at SWMU 130 comprise the second type of artificial fill. This fill was derived from the cleanup of soils around Building 776 after the 1969 fire. It consists of clayey sand with subangular quartzite cobbles. Asphalt was also encountered from 0 to 2.75 feet in BH11-87. Colors vary from moderate yellowish brown (10 YR 5/4) to pale yellowish brown (10 YR 6/2) with occasional zones of light olive gray (5 Y 5/2) indicative of reworked bedrock.

The fill at SWMU 130 overlies natural colluvial materials. In borehole BH11-87, approximately 5 feet of fill are present, with fill thickness increasing to approximately 10 feet in BH10-87 (Plate 5-2, Cross Section D-D'). The artificial fill at SWMU 130 is unsaturated.

5.2 BEDROCK GEOLOGY

The Cretaceous Arapahoe Formation underlies surficial materials at the 881 Hillside Area. Six wells were completed in various zones of the bedrock during the 1986 and 1987 drilling programs. The Arapahoe Formation beneath the 881 Hillside consists of claystones with interbedded lenticular sandstones, siltstones, and occasional lignite deposits. The Arapahoe Formation was deposited by meandering streams flowing generally from west to east off the Front Range. Sandstones were deposited in stream channels and as overbank splays, and claystones were deposited in back swamp and floodplain areas. Leaf fossils, organic matter, and lignite beds were encountered within the claystones during drilling at the 881 Hillside. Contacts between various lithologies are both gradational and sharp.

Based on correlation of the top of the sandstones in 5-87BR and 7-87BRA (Plate 5-3, Cross Section H-H'), bedrock is dipping approximately 7 degrees to the east. This dip agrees with that calculated for sandstone correlated between wells 9-87BR and 16-87BR at the 903 Pad Area (Rockwell International, 1987b).

5.2.1 Arapahoe Formation Claystones

Claystone was the most frequently encountered lithology of the Arapahoe Formation immediately below the Quaternary/Cretaceous contact (Plate 5-2 and 5-3). Claystones are generally thinly bedded and contain occasional laminae and interbeds of fine-grained sand and silt (wells 3-87BR, 45-87BR, and 47-87). Intervals of carbonaceous material and fossils (mainly plant fragments and leaves) are also common in the claystones.

Weathered bedrock was encountered directly beneath surficial materials in all of the boreholes and wells, and weathering appears to penetrate between approximately two (borehole BH16-87) and 60 feet (well 62-86BR) into bedrock. The weathered claystones are generally light olive gray (5 Y 5/2) to olive gray (5 Y 3/2) with dark yellowish orange (10 YR 6/6) stains. Stains may also occur as brown and red mottling. The weathered zone is generally consolidated and exhibits blocky structure. Iron oxide staining and concretions along with caliche are characteristic of the zone.

The weathered claystone is also characterized by mild fracturing and thus higher hydraulic conductivities than unweathered claystone. In well 5-87BR and abandoned hole 7-87BRA, claystone was mildly fractured from the alluvium/bedrock contact to depths of approximately 46 and 26 feet, respectively. A 45 degree fracture was also identified in weathered claystone in well 8-87BR at a depth of approximately 54 feet. Based on packer tests in wells 5-87BR and 8-87BR (Table 5-1), weathered claystones beneath the 881 Hillside have a mean hydraulic conductivity of 7x10-7 centimeters per second (cm/s) or 0.7 feet per year (ft/yr).

Unweathered bedrock occurs between 37.7 (well 8-87BR) and 56 feet (well 3-87BR) below ground surface. The unweathered claystones are typically darker gray than weathered claystone and have little mottling. The color ranges from olive gray (5 Y 3/2) to dark gray (N 3/0). They are also more consolidated than weathered claystones and exhibit little to no fracturing. The mean hydraulic conductivity of unweathered claystones beneath the 881 Hillside is 1x10-7 cm/s, based on packer tests in wells 3-87BR, 8-87BR, and 45-87BR (Table 5-1).

5.2.2 Arapahoe Formation Sandstones

Arapahoe sandstones were encountered beneath the 881 Hillside in holes 59-86, 62-86, 3-87BR, 5-87BR, 6-87A, 7-87BRA, 8-87BR, and 45-87BR. These sandstones are generally composed of well sorted, subrounded to rounded, very fine- to medium-grained, poorly to moderately well cemented quartz sand with up to 10% lithic fragments. The thickness of individual sandstone beds ranged from approximately five feet (well 5-87BR) to twelve feet (well 8-87BR). The sandstone in well 45-87BR (89.5-100.8 feet below ground surface) was described as homogeneous; however, they are generally thinly bedded and often contain laminae and interbeds of clay and silt (up to 2 inches thick in well 45-87BR).

TABLE 5-1

RESULTS OF CLAYSTONE PACKER TESTS

WELL NO.	MATERIAL	DEPTH OF TEST INTERVAL (feet below ground surface)	HYDRAULIC CONDUCTIVITY (cm/s)
5-87BR	Weathered Claystone	26.4 - 36.1	2×10^{-6}
	Weathered Claystone	36.1 - 45.7	1×10^{-6}
	Weathered Claystone	36.1 - 45.7	2×10^{-7}
8-87BR	Weathered Claystone	62.6 - 72.3	7×10^{-7}
GEOMETRIC MEAN (WEATHERED CLAYSTONE):			7×10^{-7}
3-87BR	Unweathered Claystone	62.9 - 72.6	1×10^{-8}
	Unweathered Claystone	62.9 - 72.6	3×10^{-7}
	Unweathered Claystone	62.9 - 72.6	2×10^{-8}
	Unweathered Claystone	74.6 - 84.2	5×10^{-8}
	Unweathered Claystone	74.6 - 84.2	4×10^{-8}
	Unweathered Claystone	88.2 - 97.9	5×10^{-7}
8-87BR	Unweathered Claystone with Lignite	83.5 - 93.1	9×10^{-8}
	Unweathered Claystone with Lignite	83.5 - 93.1	1×10^{-8}
45-87BR	Unweathered Claystone	60.6 - 70.2	2×10^{-7}
	Unweathered Claystone	60.6 - 70.2	3×10^{-6}
	Unweathered Claystone	70.2 - 79.9	2×10^{-8}
	Unweathered Claystone	70.2 - 79.9	9×10^{-7}
GEOMETRIC MEAN (UNWEATHERED CLAYSTONE):			1×10^{-7}

Sandstones encountered in holes 59-86, 67-86, 5-87BR, 6-87A, 7-87BRA, and 8-87BR are weathered. Weathered sandstones ranged from olive gray (5 Y 6/1) to moderate yellowish brown (10 YR 5/4) in color with brown, orange, and yellow iron oxide staining. Weathered sandstones were described as being friable and brittle.

Unweathered sandstones are lithologically similar to the weathered sandstones and were found in wells 45-87BR and 3-87BR, at 89.5 feet and 103 feet, respectively (Plate 5-2, Cross Section B-B', and Plate 5-3, Cross Section H-H'). Weathering penetrates into claystone as deep as 54 feet below ground surface in well 45-87BR and 56 feet below ground surface in well 3-87BR. Unweathered sandstones are generally medium dark gray (N 4/0) to pale olive (10 Y 6/2) in color with infrequent staining of browns and yellows. In well 45-87BR, a medium-grained, light gray (N 7/0) calcareous sand was encountered from 96.0 to 100.8 feet. In both wells 45-87BR and 3-87BR, claystone interbeds were encountered at 90 to 94 feet and 106.3 to 107.5 feet, respectively. Occasional intervals of silt and organic material also occurred.

Siltstones were also encountered in the Arapahoe Formation during drilling in wells 3-87BR, 8-87BR, and 45-87BR. Typically, they are medium light gray (N 6/0) in color and generally contain some very fine-grained sand. The siltstones were encountered as one to three foot thick interbeds within unweathered claystone and sandstone in wells 3-87BR, 45-87BR. Siltstone nodules were noted in core from well 8-87BR from 60 to 64 and from 78 to 82 feet below ground surface, possibly evidencing slumping of the Arapahoe shortly after deposition (before lithification).

A saturated lignite bed was encountered from approximately 85 to 88 feet below ground surface in well 8-87BR and a different lignite was found between approximately 87.8 to 88.1 feet below ground surface in well 3-87BR (Plate 5-2, Cross

Section B-B'). Very organic-rich claystones occur frequently in this stratigraphic horizon.

5.3 GROUND-WATER FLOW

Ground water occurs in surficial materials (Rocky Flats Alluvium, colluvium, terrace alluvium, valley fill alluvium, and artificial fill) and in Arapahoe sandstones and claystones at the 881 Hillside Area. These two hydraulically connected flow systems are discussed separately below.

5.3.1 Ground-Water in Surficial Materials

Recharge/Discharge Conditions

Ground water is present in surficial materials at the 881 Hillside under unconfined conditions. Recharge to the water table occurs as infiltration of incident precipitation and as seepage from ditches and creeks. In addition, the C-series ponds along Woman Creek probably recharge the valley fill alluvium.

The shallow ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and to stream and ditch flow. Hurr (1976) describes the rapid response of water levels in wells completed in Rocky Flats Alluvium to surface flows in irrigation ditches.

There are also seasonal variations in the saturated thickness of surficial materials. Figures 5-1 through 5-6 present hydrographs of water levels for alluvial wells completed in Woman Creek valley fill and terrace alluvium, and Figures 5-7 through 5-10 present hydrographs for Phase I alluvial wells completed in colluvial

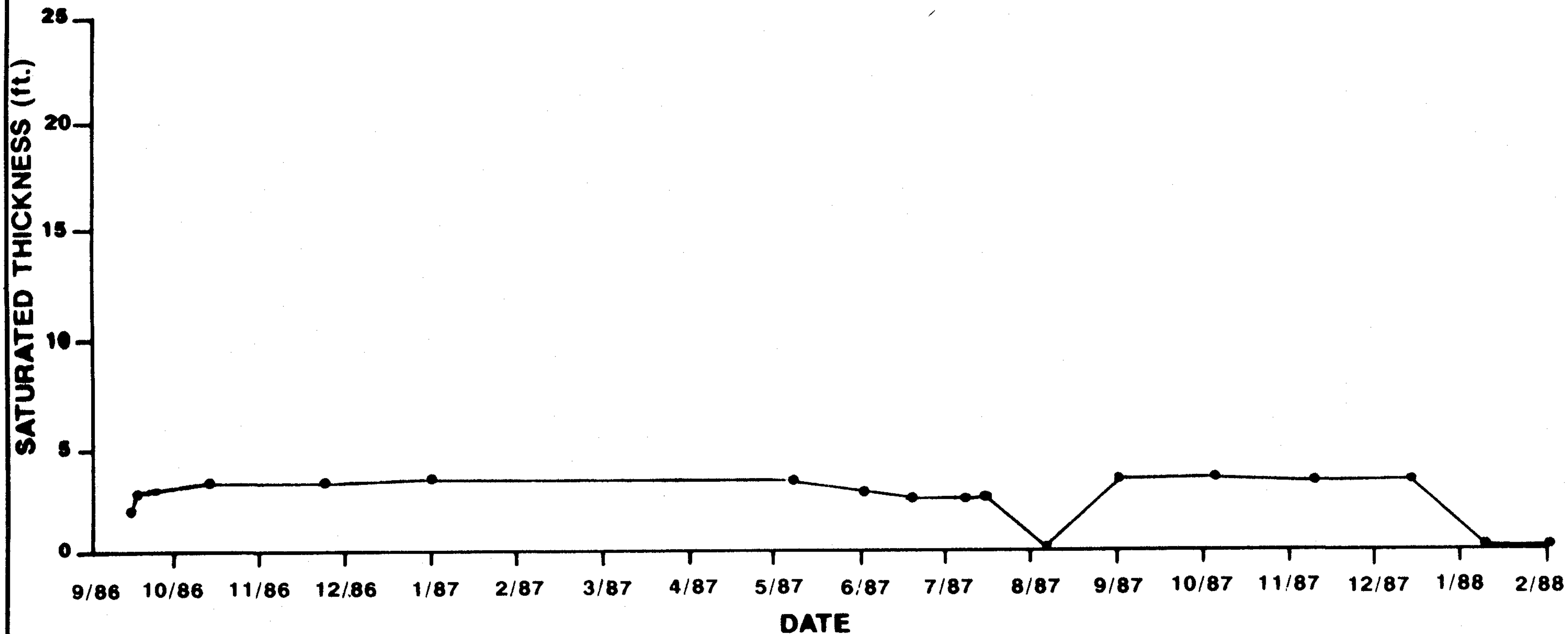


Figure 5-1:

SATURATED THICKNESS IN WELL # 68-86
From September, 1986 to February, 1988

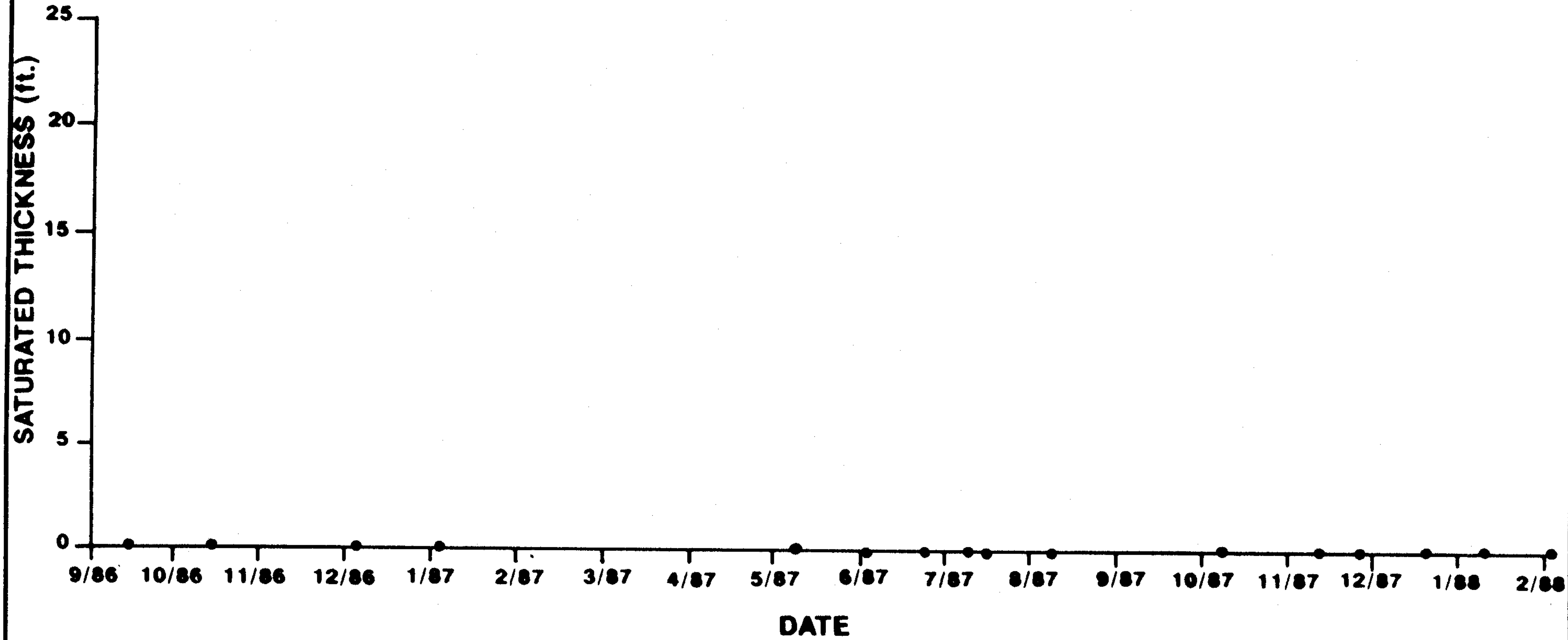


Figure 5-2:

SATURATED THICKNESS IN WELL # 58-86
From September, 1986 to February, 1988

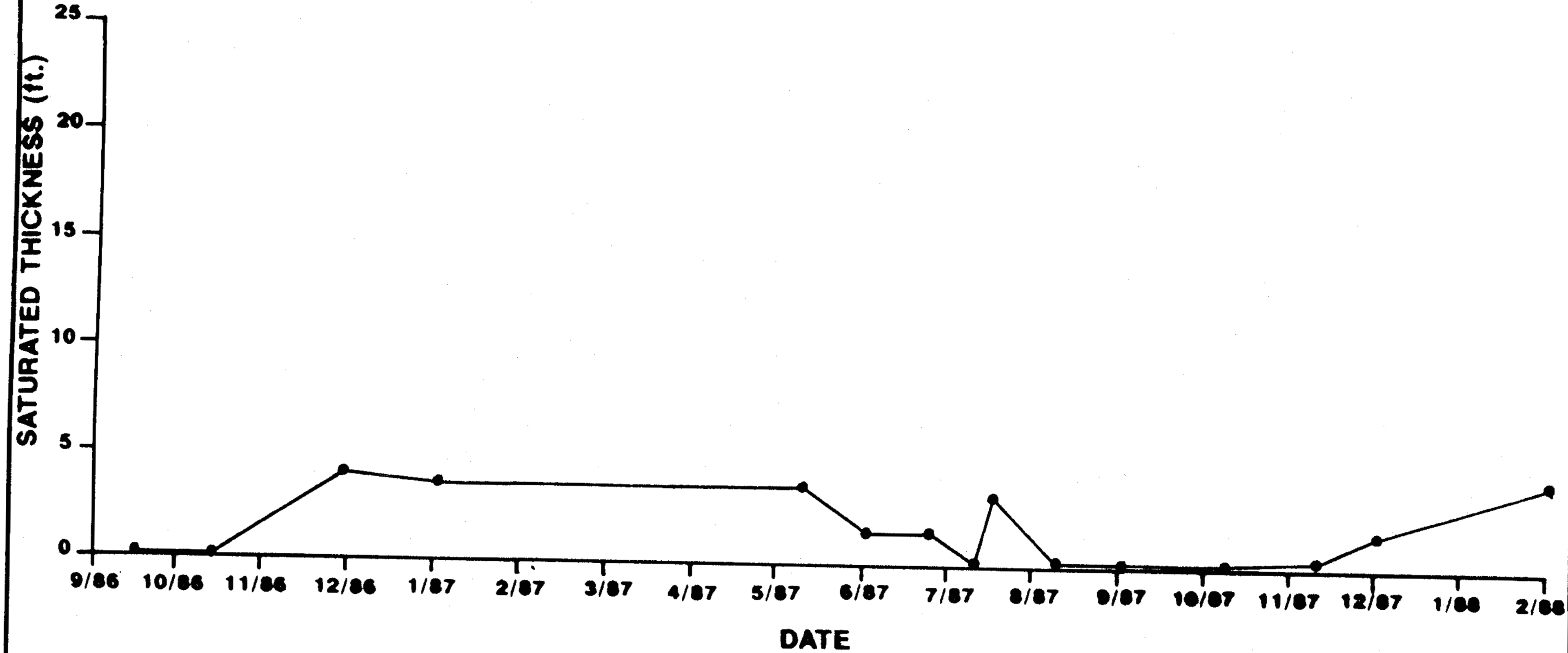


Figure 5-3:

SATURATED THICKNESS IN WELL #64-86
From September, 1986 to February, 1988

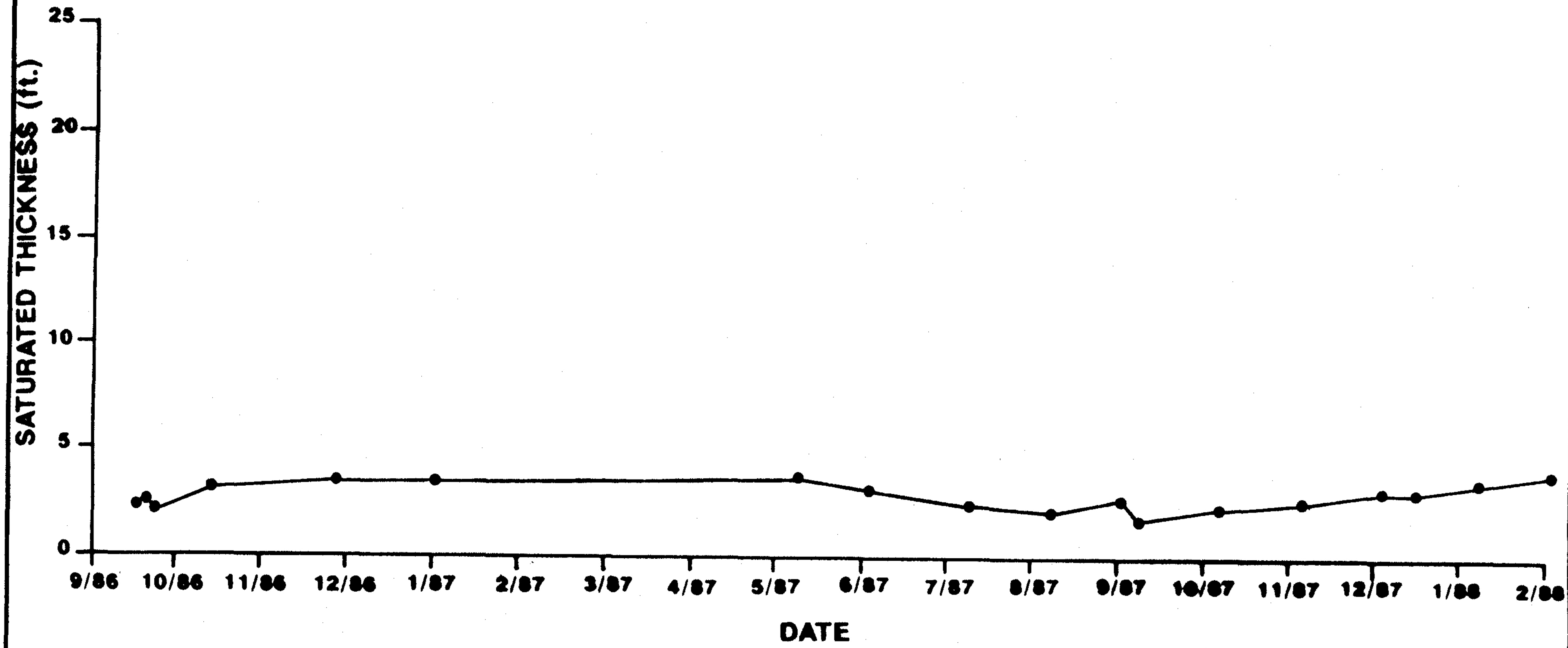


Figure 5-4:

SATURATED THICKNESS IN WELL # 65-86
From September, 1986 to February, 1988

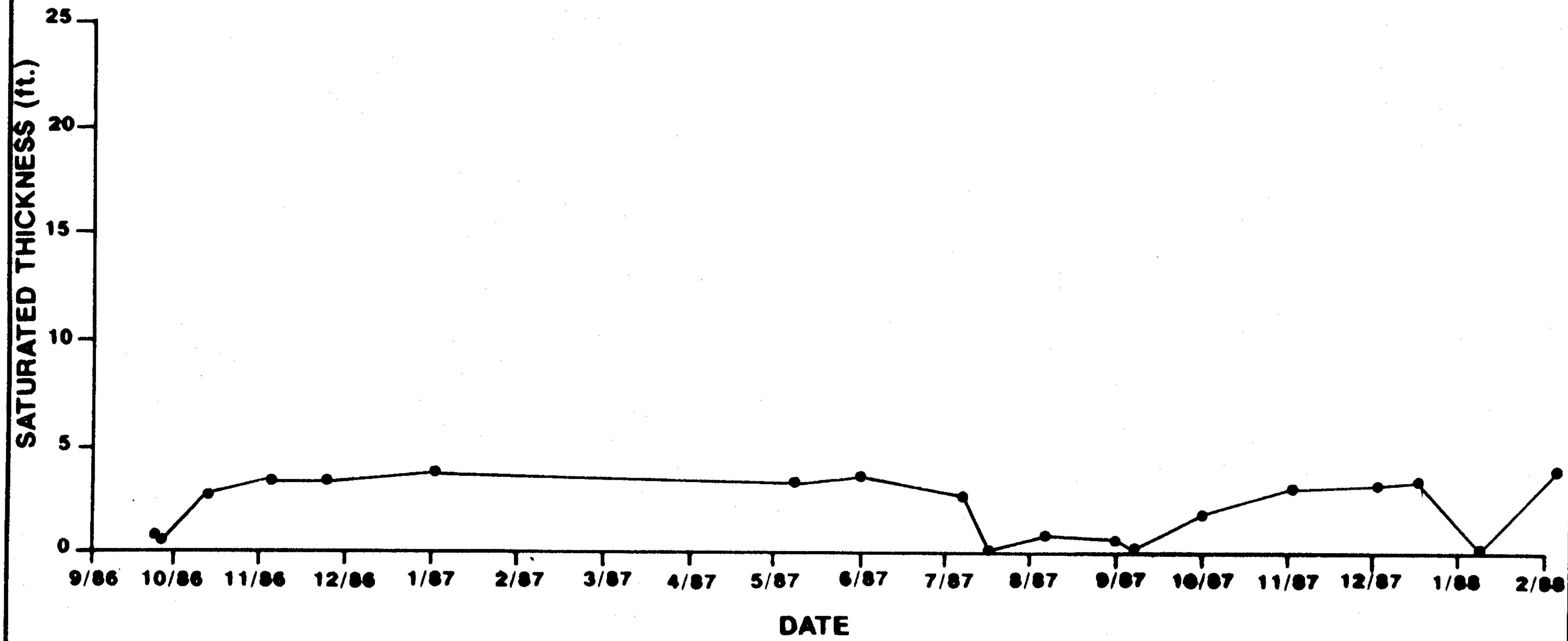


Figure 5-5:

SATURATED THICKNESS IN WELL # 66-86
From September, 1986 to February, 1988

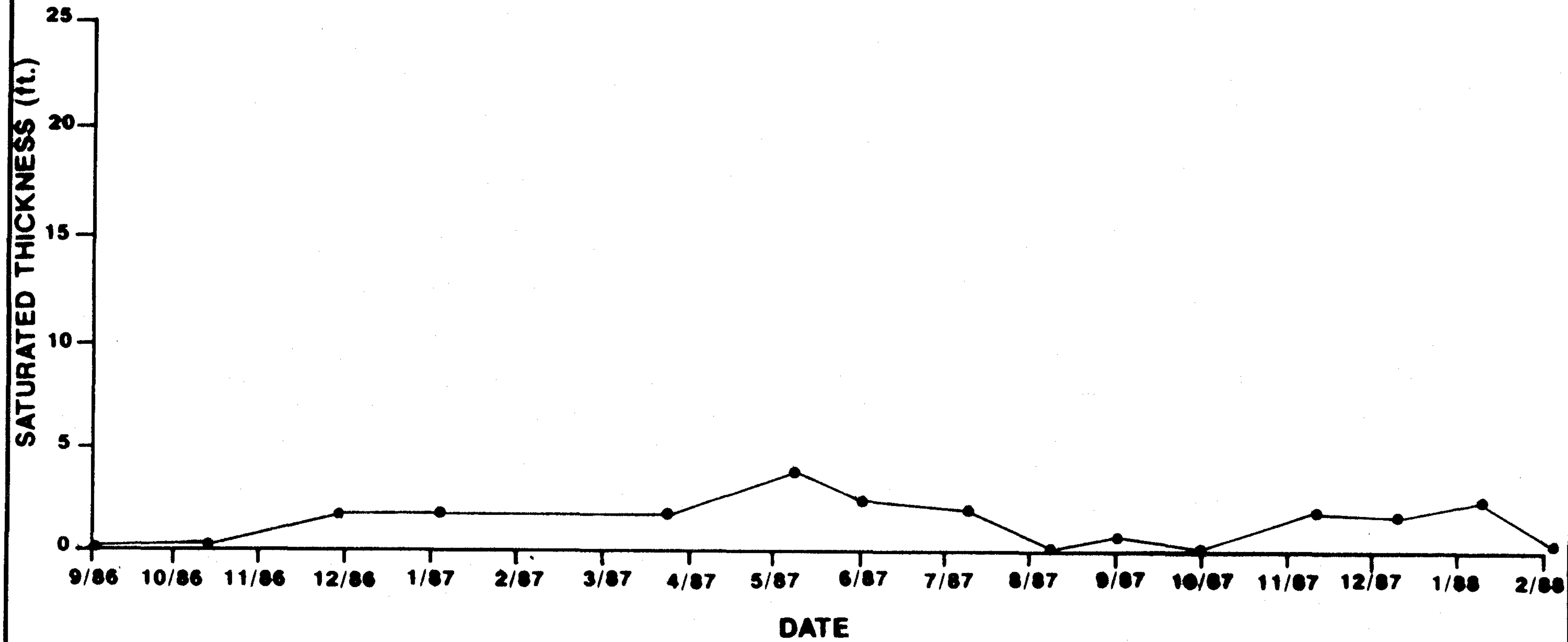


Figure 5-6:

SATURATED THICKNESS IN WELL # 1-86
From September, 1986 to February, 1988

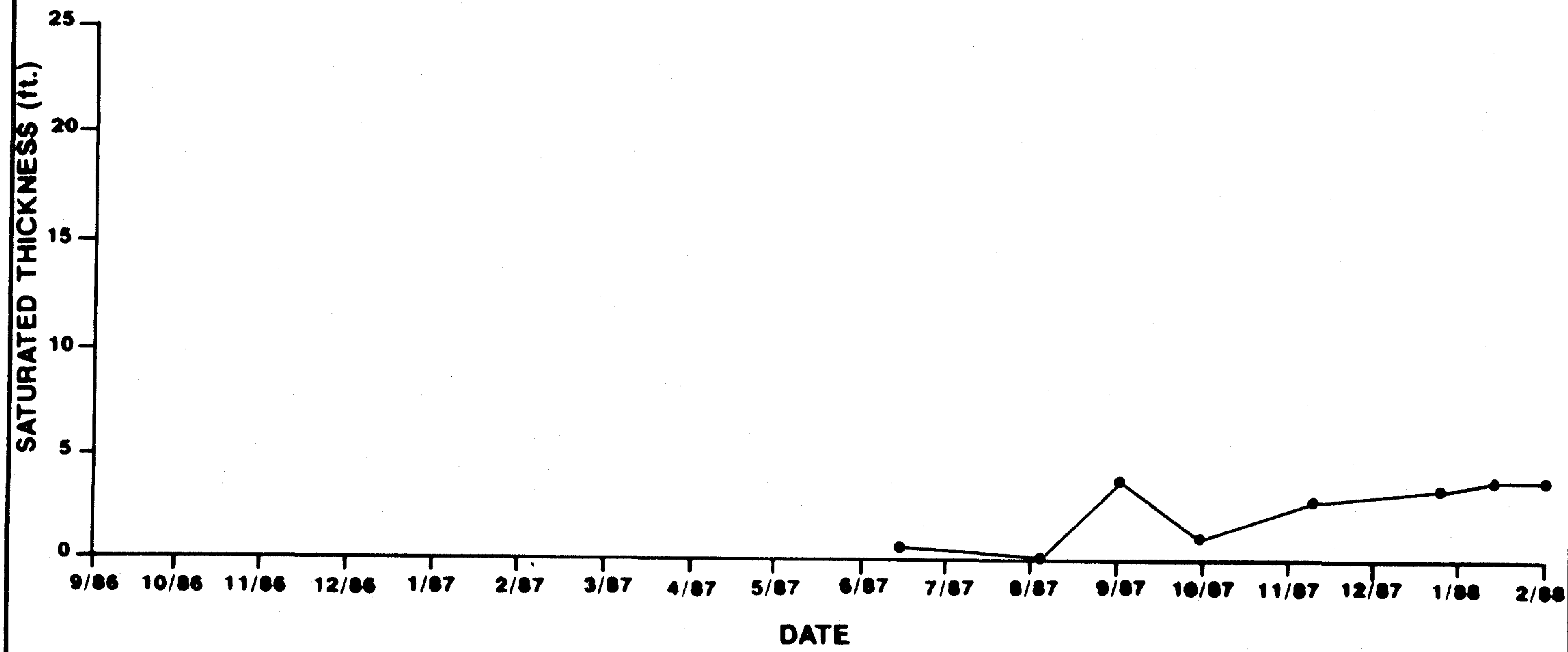


Figure 5-7:

SATURATED THICKNESS IN WELL #01-87
From June, 1987 to February, 1988

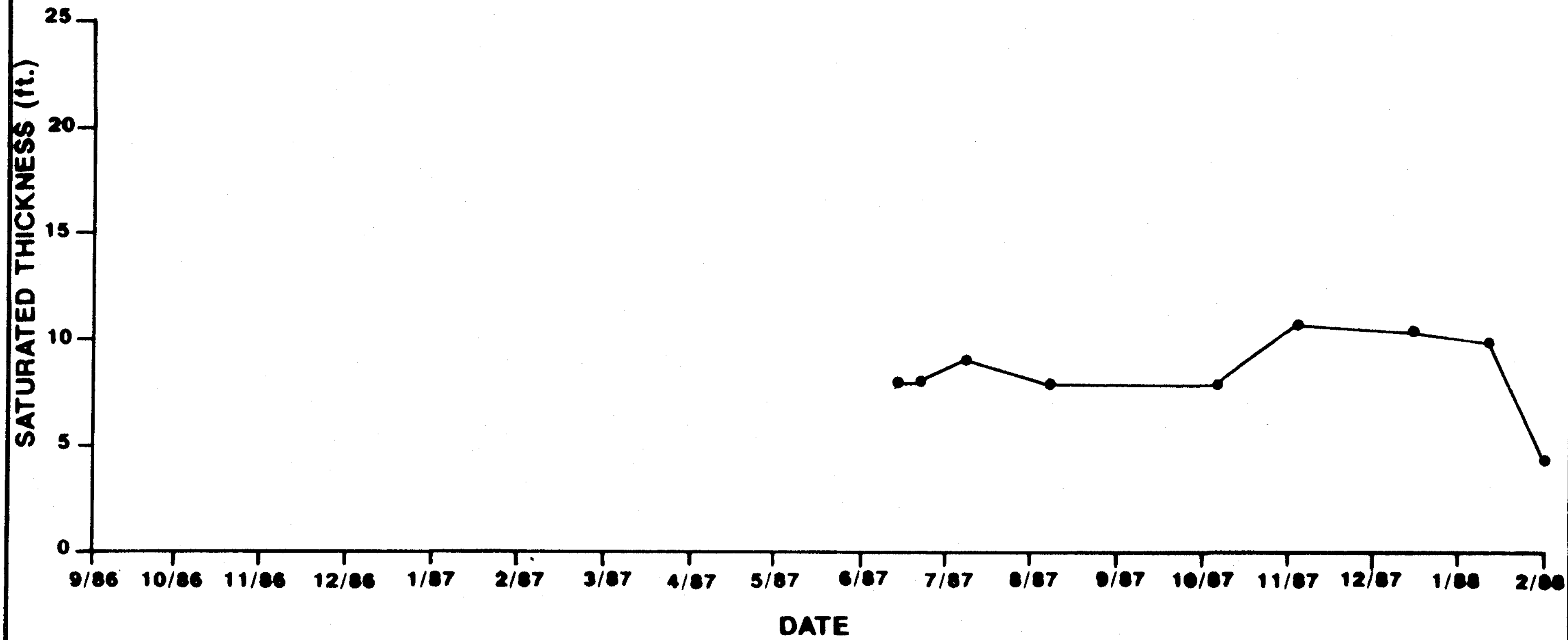


Figure 5-8:

SATURATED THICKNESS IN WELL # 02-87
From June, 1987 to February, 1988

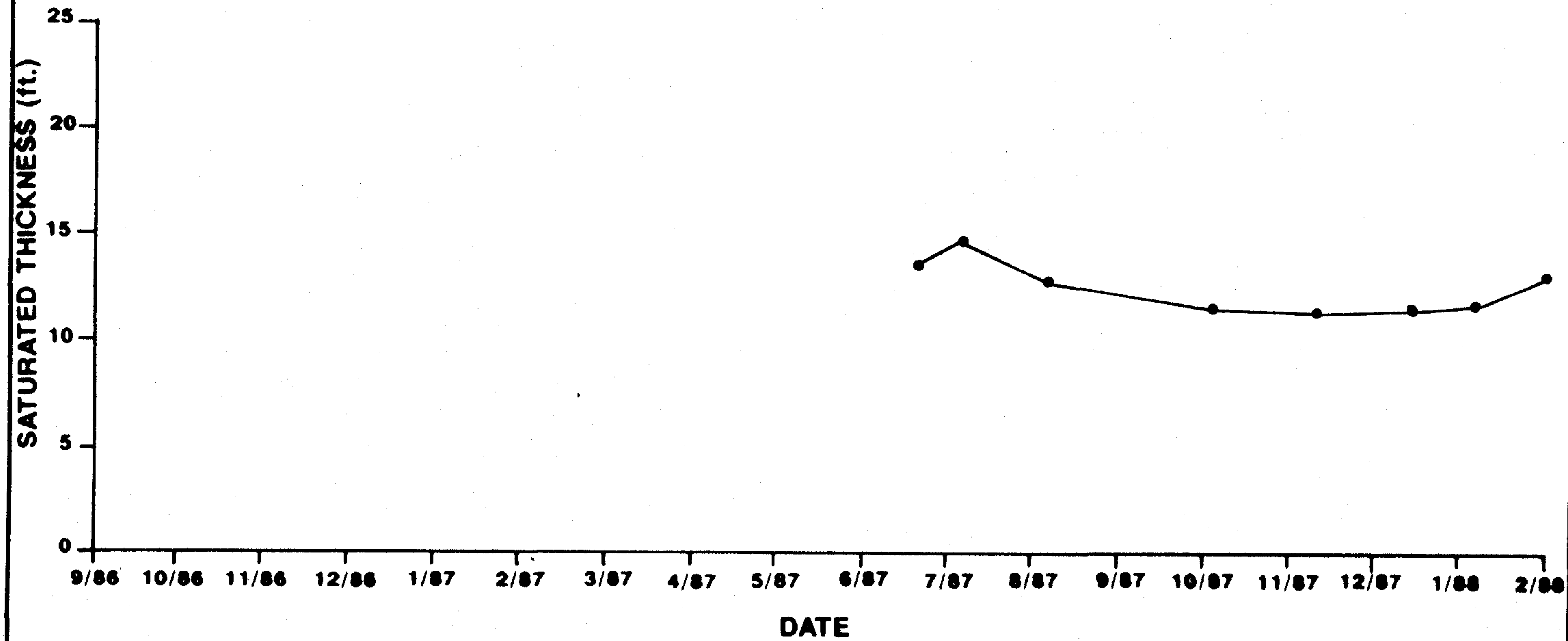


Figure 5-9:

SATURATED THICKNESS IN WELL #04-87
From June, 1987 to February, 1988

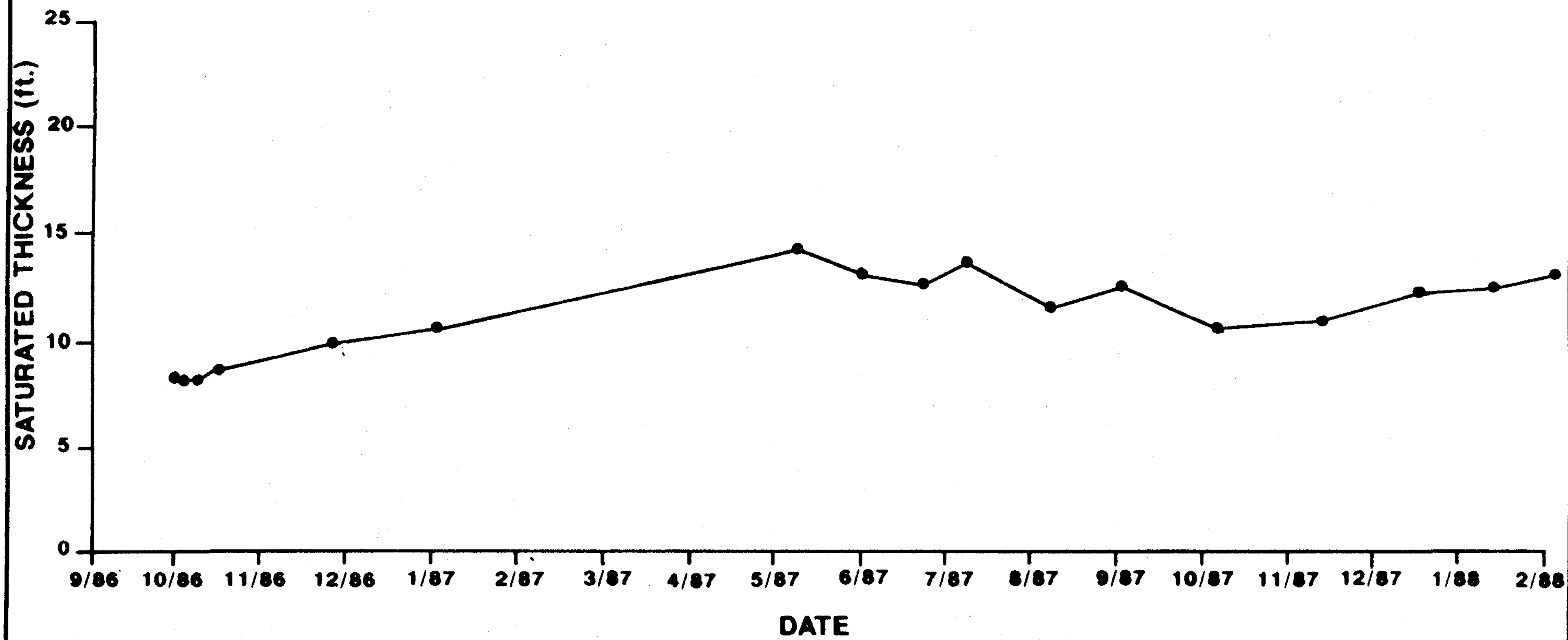


Figure 5-10:

SATURATED THICKNESS IN WELL # 69-86
From October, 1986 to February, 1988

materials on the 881 Hillside. In general, water level data are available from September, 1986 through February, 1988 for 1986 wells; although water level data are unavailable February, March, and April of 1987 for some of the 1986 wells. Water levels are available for September, 1987 through February, 1988 for Phase I 1987 wells. Hydrographs were not plotted for Phase II 1987 wells, as they were completed late in 1987 and limited water level data are available.

The saturated thickness in the Woman Creek valley fill and terrace alluviums has been less than five feet since September, 1986 (Figures 5-1 through 5-6). Water levels were lowest during the months of July, August, September, and October in wells 64-86, 65-86, 66-86, and 1-86 (Figures 5-3 through 5-6, respectively). Wells 64-86, 66-86, and 1-86 were found to be dry at least once during this period. The saturated thickness in well 68-86 (Figure 5-1) was relatively constant, although it went dry in August, 1987 and again in January, 1988. Well 58-86 contained less than 0.05 feet of water since its completion (Figure 5-2).

Although limited water level data are available for 1987 wells, seasonal water level trends for wells completed in colluvium and artificial fill on the 881 Hillside appear similar to those observed for alluvial wells along Woman Creek. The saturated thickness again appears thinnest during the dry summer and fall months and appears to increase through the winter, probably due to localized infiltration of snowmelt and precipitation.

Ground-Water Flow Directions

Ground water flows from the Rocky Flats Alluvium at the top of the 881 Hillside south through colluvial materials toward Woman Creek. At the Rocky Flats terrace edges, ground water emerges as seeps and springs at the contact between the alluvium and claystone bedrock (contact seeps), is consumed by evapotranspiration, or flows through colluvial materials following topography toward the valley fill and terrace alluviums. Once ground water reaches the valley, it either flows down-valley in the alluvium, is consumed by evapotranspiration, or discharges to Woman Creek.

Flow through colluvial materials appears to primarily occur in the gravel within the colluvium (Figure 5-3, Cross Section E-E'). Available water level data for well 47-87 indicate that ground water is below the base of the South Interceptor Ditch, although there could be discharge to the ditch during wet periods.

During the driest portions of the year, evapotranspiration can result in no flow in either the colluvium or the valley fill alluvium. Plates 5-5, 5-6, and 5-7 depict potentiometric conditions in surficial materials in August, 1987, November, 1987, and February, 1988, respectively. Wells 63-86 and 58-86 have been dry since their construction, and other alluvial wells on the hillside also go dry during portions of the year.

Ground-Water Flow Rates

Hydraulic conductivity values were developed for surficial materials from drawdown-recovery tests performed on 1986 wells during the initial site characterization (Rockwell International, 1986a) and from slug tests performed on select 1986 and 1987 wells during this remedial investigation. Drawdown-recovery tests were analyzed using the Theis equation modified for recovery, and slug tests were analyzed by the methods of Bouwer and Rice (1976). Results of these tests are summarized in Table 5-2. Test data and analyses are presented in Appendix E.

TABLE 5-2

RESULTS OF HYDRAULIC CONDUCTIVITY TESTS OF SURFICIAL MATERIALS

WOMAN CREEK VALLEY FILL

WELL NO.	DRAWDOWN-RECOVERY TESTS (cm/s)	SLUG TESTS (cm/s)
56-86	2×10^{-3}	---
65-86	3×10^{-3}	---
68-86	1×10^{-3}	---
70-86	9×10^{-4}	---

COLLUVIUM

WELL NO.	DRAWDOWN-RECOVERY TESTS (cm/s)	SLUG TESTS (cm/s)
69-86	5×10^{-4}	2×10^{-4}
2-87	4×10^{-5}	3×10^{-5}
4-87	5×10^{-4}	---

TABLE 5-4

RESULTS OF HYDRAULIC TESTS OF BEDROCK

WELL NO.	DRAWDOWN-RECOVERY TESTS (cm/s)	SLUG TESTS (cm/s)	PACKER TESTS (cm/s)
59-86BR	3×10^{-4}	---	---
62-86BR	3×10^{-5}	6×10^{-6}	---
3-87BR	3×10^{-6}	---	2×10^{-7}
5-87BR	7×10^{-5}	7×10^{-5}	1×10^{-6}
8-87BR	3×10^{-6}	---	1×10^{-7}

NOTES: Packer test results adjusted on the assumption that entire injection flow rate enters more permeable zone.

8-87BR completed in lignite; all others completed in sandstone.

Hydraulic conductivity values from drawdown-recovery tests for the Woman Creek *valley fill alluvium ranged from* 9×10^{-4} cm/s (900 ft/yr) to 3×10^{-3} cm/s (3,000 ft/yr) with a geometric mean of 1×10^{-3} cm/s (2000 ft/yr). No slug tests were performed on wells completed in Woman Creek valley fill. Using a gradient of 0.024 ft/ft (based on topography), an effective porosity of 0.1, and a mean hydraulic conductivity of 1×10^{-3} cm/s, the average ground-water velocity in Woman Creek valley fill is 250 ft/yr. Assuming that ground water flows at this velocity for about half the year, a molecule of a conservative solute would travel the 10,000 feet to the property boundary in about 80 years. The maximum ground-water velocity in Woman Creek valley fill is 740 ft/yr using the same gradient and effective porosity and the maximum hydraulic conductivity of 3×10^{-3} cm/s. This maximum possible velocity is based on one test result; other tests in the same material indicate lower velocities. Therefore, the average computed velocity is considered more representative of actual conditions throughout the Woman Creek Valley Fill.

Hydraulic conductivity values are available for three wells completed in colluvium at the 881 Hillside; two are completed in gravel layers and one is completed in clayey soil wash soil (well 69-86). The test results indicate hydraulic conductivities of 4×10^{-4} cm/s *for the gravel layers and* 3×10^{-5} cm/s for the clayey soil. Using the maximum hydraulic conductivity value of 5×10^{-4} cm/s (520 ft/yr), an average gradient of 0.15, and an assumed effective porosity of 0.1, the maximum ground-water velocity through colluvial materials is 780 ft/yr, although this is not likely to occur because the gravel lenses are not continuous (See discussions in Section 5.4.2.2). In addition, after traveling the length of the colluvium, a dissolved constituent would also have to move through the entire lenth of the valley Fill Alluvium before reaching the property boundary..

5.3.2 Bedrock Ground-Water Flow System

Recharge Conditions

The majority of ground-water flow in the Arapahoe Formation occurs in the sandstones contained within the claystones. Ground-water recharge to sandstones occurs as infiltration from alluvial ground water where sandstones subcrop beneath the alluvium and by leakage through the claystones overlying the sandstones.

There is a strong downward gradient between ground water in surficial materials and bedrock. This has been demonstrated previously at the Plant (Hurr, 1976 and Rockwell International, 1986a), and additional vertical gradient data are provided by this remedial investigation. Table 5-3 presents vertical hydraulic gradients calculated for alluvial/bedrock well pairs 2-87 and 3-87BR, 43-87 and 5-87BR, and the three well cluster 69-86, 59-86 (bedrock well), and 8-87BR. Calculated vertical gradients range from about 2 to 0.3. Unsaturated conditions are indicated between the colluvium and the first permeable sandstone at wells 5-87BR and 59-86BR. The presence of unsaturated conditions and high vertical gradients where subsurface materials are continuously saturated indicates that the intervening material (claystone) has a very low hydraulic conductivity.

Ground-Water Flow Directions

Ground-water flow within individual sandstones is from west to east at an average gradient of 0.03 ft/ft based on wells completed in the same sandstones at the 903 Pad and East Trenches Areas (Rockwell International, 1987b) and on regional data (Robson and others, 1981a).

TABLE 5-3

VERTICAL GRADIENTS

WELL	GROUND ELEVATION (ft AMSL)	ELEVATION OF POTENTIOMETRIC SURFACE (ft AMSL)	DEPTH TO BASE OF PERMEABLE ZONE (ft)	ELEVATION OF BASE OF PERMEABLE ZONE (ft AMSL)	DEPTH TO TOP OF PERMEABLE ZONE (ft)	ELEVATION OF TOP OF PERMEABLE ZONE (ft)	THICKNESS OF SEPARATOR (ft)	CALCULATED DOWNWARD VERTICAL GRADIENT
2-87	5930.56	5931.13	8.75	5921.81	---	---		
3-87BR	5930.58	5888.44	---	---	103.1	5827.48	94.33	0.45
43-87	5924.92	5918.39	12.0	5912.92	---	---		
5-87BR	5927.76	5883.96	---	---	42.3	5885.46	27.46	1.25
69-86	5921.19	5920.37	13.3	5907.89	---	---		
59-86BR	5914.32	5889.63	26.5	5887.82	19.0	5895.32	12.57	2.45
8-87BR	5919.70	5874.10	---	---	85.0	5834.70	53.12	0.29

NOTES: Potentiometric surface elevations from January 1988 data except 68-86, 59-86BR, and 8-87BR are February 1988 data (59-86BR was dry in January 1988).

Vertical gradients greater than 1.0 indicate unsaturated conditions.

Ground-Water Flow Velocities

Hydraulic conductivity values for Arapahoe sandstones were estimated from drawdown-recovery tests performed in 1986, slug tests performed in 1987, and packer tests performed in 1986 and 1987. Table 5-2 summarizes the results of these tests. Data, analyses, and results of each test are provided in Appendix E.

Hydraulic conductivity values from drawdown-recovery tests and slug tests are in good agreement; however, packer test results are approximately one order of magnitude less than results from the other two test methods. The packer tests are probably influenced by injection of clayey cuttings into the interstices between the sandstone grains during drilling and are therefore considered less reliable than the drawdown-recovery and slug tests. Packer tests of claystones described earlier in this section are considered reliable because the injection of clayey cuttings into the formation should have a lesser effect in low hydraulic conductivity materials.

Hydraulic conductivity values were in good agreement between drawdown-recovery and slug tests. The hydraulic conductivity of the sandstones ranged from $3x10^{-6}$ cm/s to $3x10^{-4}$ cm/s with a geometric mean of $3x10^{-5}$ cm/s. The wide variation of results for a similar geologic material is reasonable given that the silt content of the sandstones varies from nill to 12 percent or more.

The maximum horizontal ground-water velocity in sandstone would be about 36 ft/yr using a hydraulic conductivity of $3x10^{-4}$ cm/s, an average horizontal gradient of 0.03 ft/ft, and an effective porosity of 0.256. The effective porosity value is an average of laboratory test results reported in Robson (1983). The minimum velocity would be 0.36 ft/yr using a hydraulic conductivity of $3x10^{-6}$ cm/s and the same gradient and effective porosity. Ground water would flow at these rates only if the sandstone unit is continuous or has good interconnection with an adjacent unit. To date, lateral continuity of sandstone units along strike has been demonstrated to be small and only a few correlations have been made along dip (see cross sections).

5.4 GROUND-WATER CHEMISTRY

This section describes the ground-water chemical conditions in the 881 Hillside Area. The significance of the chemical conditions is evaluated by comparison with background, except for the Hazardous Substances List (HSL) organics which imply contamination by their mere presence. However, because chemical constituents elevated above background, particularly major ion concentrations, may also result from natural variations in alluvial and bedrock geochemistry, the inorganic chemistry of the ground water at various monitor wells is examined in some detail.

This evaluation of chemical conditions is based on all data collected since 1986 when detailed ground-water investigations began at the plant. Some of the 1986 wells have five quarters of analytical results, i.e., the last quarter of 1986 (initial site characterization results) and the four quarters of 1987. Wells completed in 1987 have less extensive databases. Table 5-4 lists the analyses performed on ground-water samples, and Tables 5-5 through 5-8 summarize the availability of ground-water quality data used in this report.

TABLE 5-4

GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS
pH
Specific Conductance
Temperature
Dissolved Oxygen*

INDICATORS
Total Dissolved Solids
Total Suspended Solids*

METALS**
Hazardous Substances List - Metals
Beryllium
Calcium
Chromium (hexavalent)
Iron
Lithium
Magnesium
Manganese
Potassium
Sodium
Strontium
Zinc

ANIONS
Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate

ORGANICS
Hazardous Substances List - Volatiles***
Oil and Grease

RADIONUCLIDES
Gross Alpha
Gross Beta
Uranium 233, 234, 235, and 238
Americium 241
Plutonium 239
Strontium 90
Cesium 137
Tritium

TABLE 5-4

GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS (CONTINUED)

* For surface water samples only

** Dissolved metals for ground-water samples, total and dissolved metals for surface water samples

*** Ground-water samples from the first, second, and third quarters of 1987, and all surface water samples were analyzed for 9 of the HSL volatiles. These volatiles are the chlorinated solvents historically detected in the ground water and are as follows: PCE, TCE, 1,1-DCE, 1,2-DCA, t-1,2-DCE, 1,1,1-TCA, 1,1,2-TCA, CCl_4 and $CHCl_3$.

Table 5-5

GROUND WATER SAMPLE INFORMATION

ALLUVIAL WELLS WEST OF PLANT

WELL	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS			
NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	METALS	INORGANICS	RADIOCHEMISTRY
0782	DRY	08/20/87								
0782	DRY	12/05/87								
1081	G108108860	08/08/86	Routine				8608-014-001	8608-014-09	8608-014-10	1000-000-247
1081	10-81-05-11-87	05/11/87	Routine				0187-881-089	0187-881-089	0187-881-088	0187-881-089
1081	10-81-06-18-87	06/18/87	Routine				0287-881-052	0287-881-052	0287-881-054	0287-881-052
1081	10-81-08-20-87	08/20/87	Routine	7.00	100	16.4	0387-881-091	0387-881-102	0387-881-098	0387-881-077
1081	10-81-01-12-88	01/12/88	Routine	7.00	225	12.2		0487-881-073	0487-881-073	
4786	G478611860	11/07/86	Routine	6.50	72	10.0	8611-014-001	8611-014-02	8611-014-03	1000-000-290
4786	G478611862	11/07/86	Field Duplicate	6.50	72	10.0	8611-014-006	Insufficient Sample	Insufficient Sample	1000-000-292
4786	47-86-05-13-87	05/13/87	Routine	6.00	195	12.0	0187-881-096	0187-881-096	0187-881-095	0187-881-098
4786	47-86-06-22-87	06/22/87	Routine	7.40	164	11.9	0287-881-060	0287-881-060	0287-881-063	0287-881-060
4786	47-86-08-13-87	08/13/87	Routine	7.30	159	13.1	0387-881-081	0387-881-091	0387-881-089	0387-881-067
4786	47-86-10-05-87	10/05/87	Field Split				8710-017-0020	No Sample	No Sample	No Sample
4786	47-86-10-05-87	10/05/87	Routine	6.50	163	15.1	0487-881-010	0487-881-011	0487-881-010	0487-881-007
4986	G498611860	11/24/86	Routine	6.10	295	11.5	8612-002-021	8612-002-22	8612-002-23	1000-000-293
4986	49-86-04-08-87	04/08/87	Routine	7.00	400	11.0	0187-881-041	0187-881-041	0187-881-043	0187-881-043
4986	49-86-06-18-87	06/18/87	Routine	6.20	330	11.7	0287-881-053	0287-881-053	0287-881-057	0287-881-053
4986	49-86-08-24-87	08/24/87	Routine	7.40	280	12.5	0387-881-096	0387-881-106	0387-881-102	0387-881-085
4986	49-86-12-14-87	12/14/87	Routine	7.20	188	8.8	0487-881-065	0487-881-062	0487-881-048	0487-881-016
5086	G508610860	10/31/86	Routine	6.80	245	11.0	8611-004-021	8611-004-22	8611-004-23	1000-000-294
5086	G508610862	10/31/86	Field Duplicate	6.90	230	11.5	8611-004-016	Insufficient Sample	Insufficient Sample	1000-000-295
5086	50-86-05-11-87	05/11/87	Routine	7.00	280		0187-881-081	0187-881-081	0187-881-084	0187-881-084
5086	50-86-06-16-87	06/16/87	Routine	7.50	166	13.6	0287-881-049	0287-881-049	0287-881-051	0287-881-049
5086	50-86-08-14-87	08/14/87	Routine	6.50	217	14.5	0387-881-085	0387-881-092	0387-881-090	0387-881-068
5086	50-86-12-10-87	12/10/87	Routine	7.00	261	11.5	0487-881-055	0487-881-047	0487-881-042	0487-881-014
5186	G518611860	11/07/86	Routine				8611-014-016	8611-014-017	8611-014-18	1000-000-296
5186	51-86-05-13-87	05/13/87	Routine				0187-881-093	0187-881-093	0187-881-097	0187-881-099
5186	51-86-06-17-87	06/17/87	Routine	7.20	187	13.2	0287-881-058	0287-881-058	0287-881-052	0287-881-058
5186	51-86-06-17-87	06/17/87	Routine				0287-881-058	0287-881-058	0287-881-052	0287-881-058
5186	51-86-08-19-87	08/19/87	Routine	7.40	215	15.5	0387-881-090	0387-881-098	0387-881-095	0387-881-074
5186	51-86-12-10-87	12/10/87	Routine	7.10	170	11.5	0487-881-058	0487-881-048	0487-881-043	0487-881-015
5386	DRY	11/12/86								
5386	DRY	07/13/87								
5386	DRY	12/03/87								
5586	G558610860	10/16/86	Routine	6.40	225	12.5	8610-044-0210	8610-044-22	8610-044-23	1000-000-299
5586	55-86-05-18-87	05/18/87	Routine	6.20	244	10.7	0187-881-104	0187-881-104	0187-881-108	0187-881-110

Table 5-5 (cont.)

GROUND WATER SAMPLE INFORMATION

ALLUVIAL WELLS WEST OF PLANT

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS			
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	METALS	INORGANICS	RADIOCHEMISTRY
5586	55-86-05-27-87	05/27/87	Routine	7.20	201	12.0	0287-881-015	0287-881-015	0287-881-015	0287-881-015
5586	55-86-07-13-87	07/13/87	Routine	7.00	225	13.3	0387-881-032	0387-881-143	0387-881-041	0387-881-014
5586	55-86D-07-13-87	07/13/87	Field Duplicate				0387-881-033	0387-881-144	0387-881-042	0387-881-111
5586	55-86-08-10-87	08/10/87	Routine	6.50	212	13.6	Insufficient Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
5586	55-86-09-30-87	09/30/87	Field Split				8710-006-0070	No Sample	No Sample	No Sample
5586	55-86-09-30-87	09/30/87	Routine	7.10	177	14.8	0487-881-003	0487-881-003	0487-881-003	0487-881-002
5586	55-86-10-01-87	10/01/87	Field Split				No Sample	No Sample	No Sample	0187-123-011
5686	G568610860	10/02/86	Routine	7.30	300	18.0	8610-011-06	8610-011-07	8610-011-08	1000-000-300
5686	56-86-05-19-87	05/19/87	Routine	6.70	295	13.9	0187-881-108	0187-881-108	0187-881-110	0187-881-112
5686	56-86-05-27-87	05/27/87	Routine	6.60	318	13.6	0287-881-013	0287-881-013	0287-881-013	0287-881-013
5686	56-86-07-14-87	07/14/87	Routine	6.60	295	19.9	0387-881-035	0387-881-145	0387-881-043	0387-881-016
5686	56-86-09-30-87	09/30/87	Field Split				8710-006-0080	No Sample	No Sample	No Sample
5686	56-86-09-30-87	09/30/87	Routine	6.30	276	19.3	0487-881-004	0487-881-004	0487-881-004	0487-881-003
5686	56-86-10-01-87	10/01/87	Field Split				No Sample	No Sample	No Sample	0187-123-010

Table 5-6

GROUND WATER SAMPLE INFORMATION

BEDROCK WELLS WEST OF PLANT

WELL	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS			
NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	METALS	INORGANICS	RADIOCHEMISTRY
4686	G468611860	11/13/86	Routine	9.80	320	11.0	8611-027-016	8611-027-17	Insufficient Sample	Insufficient Sample
4686	46-86-05-14-87	05/14/87	Routine	5.50	424	14.5	0187-881-101	0187-881-101	0187-881-104	0187-881-106
4686	46-86-06-22-87	06/22/87	Routine	7.90	370	12.3	0287-881-059	0287-881-059	0287-881-062	0287-881-059
4686	46-86-08-13-87	08/13/87	Routine	8.00	357	13.2	0387-881-080	0387-881-090	0387-881-088	0387-881-066
4686	46-86-10-05-87	10/05/87	Field Split				8710-017-0010	No Sample	No Sample	No Sample
4686	46-86-10-05-87	10/05/87	Routine	7.00	403	13.4	0487-881-009	0487-881-010	0487-881-009	0487-881-006
4686	46-86-10-06-87	10/06/87	Field Split				No Sample	No Sample	No Sample	0187-123-017
4886	48-86-04-08-87	04/08/87	Routine				0187-881-039	0187-881-039	0187-881-042	0187-881-042
4886	48-86-06-18-87	06/18/87	Routine	9.60	238	13.4	0287-881-054	0287-881-054	0287-881-058	0287-881-054
4886	48-86-08-24-87	08/24/87	Routine	8.60	351	12.7	0387-881-095	0387-881-105	0387-881-101	0387-881-084
4886	48-86-12-14-87	12/14/87	Routine	9.30	198	9.0	0487-881-064	0487-881-052	0487-881-047	
5286	52-86-10-02-86	10/02/86	Field Split				8710-006-0030	No Sample	No Sample	No Sample
5286	52-86-05-13-87	05/13/87	Routine	7.00	244	13.4	0187-881-125	Insufficient Sample	0187-881-098	0187-881-100
5286	52-86-06-18-87	06/18/87	Routine	10.60	224	13.1	0287-881-084	0287-881-084	0287-881-056	0287-881-079
5286	52-86-08-18-87	08/18/87	Routine	8.80	246	15.4	0387-881-089	0387-881-095	0387-881-093	0387-881-072
5286	52-86-10-02-87	10/02/87	Field Split				No Sample	No Sample	No Sample	0187-123-008
5286	52-86-10-02-87	10/02/87	Field Duplicate				Insufficient Sample	Insufficient Sample	Insufficient Sample	0187-123-009
5286	52-86-10-02-87	10/02/87	Routine	9.40	187	13.6	0487-881-005	0487-881-006	0487-881-005	0487-881-004
5486	G548611860	11/25/86	Routine	6.50	480	10.5	8612-002-051	8612-002-52	8612-02-53	1000-000-297
5486	54-86-04-08-87	04/08/87	Routine	6.70	750	14.0	0187-881-045	0187-881-045	0187-881-045	0187-881-045
5486	54-86-05-27-87	05/27/87	Routine	7.70	684	13.8	0287-881-014	0287-881-014	0287-881-014	0287-881-014
5486	54-86-07-13-87	07/13/87	Routine	7.10	768	14.0	0387-881-031	0387-881-141	0387-881-040	0387-881-013
5486	54-86-08-10-87	08/10/87	Routine	7.30	771	13.9	Insufficient Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
5486	54-86-09-30-87	09/30/87	Field Split				8710-006-0060	No Sample	No Sample	No Sample
5486	54-86-09-30-87	09/30/87	Routine	7.10	658	15.4	0487-881-002	0487-881-002	0487-881-002	0487-881-001
5486	54-86-10-01-87	10/01/87	Field Split				No Sample	No Sample	No Sample	0187-123-012

Table 5-7

GROUND WATER SAMPLE INFORMATION

ALLUVIAL WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS			
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	METALS	INORGANICS	RADIOCHEMISTRY
0186	DRY	08/29/86								
0186	1-86-05-11-87	05/11/87	Routine	7.60	3020	11.0	0187-881-082	0187-881-082	0187-881-085	0187-881-085
0186	1-86-06-01-87	06/01/87	Routine	8.80	550	13.6	0287-881-022	0287-881-022	0287-881-027	0287-881-022
0186	1-86-07-16-87	07/16/87	Routine	6.50	571	20.9	0387-881-041	0387-881-043	0387-881-047	0387-881-020
0187	DRY	10/12/87								
0287	2-87-05-29-87	05/29/87	Routine	7.20	830	12.2	Insufficient Sample	0587-881-002	0587-881-002	0587-881-002
0287	GW287BH03	06/24/87	Field Split				8706-004-0050	No Sample	No Sample	No Sample
0287	2-87-07-08-87	07/08/87	Routine	7.60	1063	15.6	0387-881-025	0387-881-137	0387-881-036	0387-881-008
0287	2-87-10-07-87	10/07/87	Routine	7.60	829	17.7	0687-881-013	0687-881-011	0687-881-012	0687-881-011
0287	2-87-10-08-87	10/08/87	Field Split				No Sample	No Sample	No Sample	0187-123-015
0487	4-87-05-20-87	05/20/87	Routine				0587-881-001	0587-881-001	0587-881-001	0587-881-001
0487	GW0487	05/26/87	Field Split	7.70	1970	13.1	8705-057-0100	No Sample	No Sample	No Sample
0487	4-87-07-08-87	07/08/87	Routine	7.40	3660	16.2	0387-881-027	0387-881-139	0387-881-038	0387-881-010
0487	4-87-10-14-87	10/14/87	Routine	7.10	2430	12.7	0687-881-017	0687-881-017	0687-881-018	0687-881-013
0687	6-87-07-28-87	07/28/87	Routine	6.90	1721	18.8	0387-881-059	0387-881-068	0387-881-067	0387-881-047
0687	6-87-08-25-87	08/25/87	Routine				0387-881-098	Insufficient Sample	Insufficient Sample	Insufficient Sample
0687	6-87-10-14-87	10/14/87	Routine	7.20	2110	14.5	0687-881-018	Insufficient Sample	Insufficient Sample	Insufficient Sample
0687	6-87-10-14-87	10/14/87	Field Split				8710-053-0030	No Sample	No Sample	No Sample
0974	G097408860	08/29/86	Routine	7.30	1700	14.0	8609-004-0010	8609-004-002	8609-004-003	1000-000-241
0974	9-74-03-09-87	03/09/87	Routine				0187-881-004	0187-881-004	0187-881-005	0187-881-004
0974	9-74-04-09-87	04/09/87	Routine				0187-881-047	0187-881-047	0187-881-049	0187-881-049
0974	9-74-05-21-87	05/21/87	Routine				0287-881-001	0287-881-001	0287-881-001	0287-881-001
0974	9-74-07-01-87	07/01/87	Routine	7.00	2010	13.6	0387-881-017	0387-881-020	0387-881-026	0387-881-003
0974	9-74-10-20-87	10/20/87	Routine	7.00	2230	15.2	0487-881-023	0487-881-026	0487-881-024	0487-881-010
0974	9-74-10-28-87	10/28/87	Field Split				8710-072-0010	No Sample	No Sample	No Sample
0974	9-74-11-17-87	11/17/87	Routine				0487-881-038	0487-881-037	Insufficient Sample	Insufficient Sample
1074	10-74-05-21-87	05/21/87	Routine				0287-881-002	0287-881-002	0287-881-002	0287-881-002
1074	DRY	07/01/87								
1074	10-74-10-20-87	10/20/87	Field Split	7.40	2460	14.8	8710-072-0020	No Sample	No Sample	No Sample
1074	10-74-10-20-87	10/20/87	Routine				0487-881-024	Insufficient Sample	Insufficient Sample	Insufficient Sample
1674	DRY	08/27/86		6.30	180	15.5				
1674	DRY	09/08/87								
4387	43-87-12-17-87	12/17/87	Routine	8.10	1785	10.8	0487-881-077	0487-881-065	0487-881-060	0487-881-017
4487	DRY	11/14/87								

Table 5-7 (cont.)

GROUND WATER SAMPLE INFORMATION

ALLUVIAL WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS			
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	METALS	INORGANICS	RADIOCHEMISTRY
4787	47-87-11-30-87	11/30/87	Routine				0487-881-046	Insufficient Sample	Insufficient Sample	Insufficient Sample
4887	48-87-11-18-87	11/18/87	Field Split	7.50	380	13.0	8711-052-0004	No Sample	No Sample	No Sample
4887	48-87-11-18-87	11/18/87	Routine				0487-881-042	Insufficient Sample	Insufficient Sample	Insufficient Sample
4987	DRY	11/18/87								
5087	50-87-11-18-87	11/18/87	Field Split	7.20	488	13.5	8711-052-0003	No Sample	No Sample	No Sample
5087	50-87-11-18-87	11/18/87	Routine				0487-881-041	Insufficient Sample	Insufficient Sample	Insufficient Sample
5187	DRY	11/23/87								
5287	52-87-11-22-87	11/22/87	Field Split	6.80	1141	12.8	8711-063-0002	No Sample	No Sample	No Sample
5287	52-87-11-24-87	11/24/87	Routine				0487-881-048	0487-881-080	0487-881-084	0487-881-012
5387	53-87-11-18-87	11/18/87	Field Split	7.70	292	9.2	8711-052-0002	No Sample	No Sample	No Sample
5387	53-87-11-18-87	11/18/87	Routine				0487-881-039	Insufficient Sample	Insufficient Sample	Insufficient Sample
5487	54-87-11-18-87	11/18/87	Field Split	7.30	440	9.2	8711-052-0001	No Sample	No Sample	No Sample
5487	54-87-11-18-87	11/18/87	Routine				0487-881-040	Insufficient Sample	Insufficient Sample	Insufficient Sample
5587	55-87-10-30-87	10/30/87	Routine				0487-881-045	Insufficient Sample	Insufficient Sample	Insufficient Sample
5886	DRY	09/13/86								
5886	DRY	07/14/87								
5886	DRY	10/12/87								
6186	61-86-03-10-87	03/10/87	Routine	7.40	420	10.0	0187-881-005	0187-881-005	0187-881-006	0187-881-005
6186	61-86-05-04-87	05/04/87	Routine	7.10	430	9.0	0187-881-070	0187-881-070	0187-881-077	0187-881-077
6186	61-86-06-23-87	06/23/87	Routine	7.40	396	14.2	0287-881-064	0287-881-064	0287-881-068	0287-881-064
6186	61-86-08-25-87	08/25/87	Routine	6.90	451	18.7	0387-881-099	0387-881-108	0387-881-104	0387-881-087
6186	DRY	10/12/87								
6386	DRY	10/06/86								
6386	DRY	07/06/87								
6386	DRY	10/14/87								
6486	DRY	09/13/86								
6486	64-86-04-29-87	04/29/87	Routine	7.30	1000	12.0	0187-881-065	0187-881-065	0187-881-068	0187-881-068
6486	64-86-05-28-87	05/28/87	Routine	6.80	627	13.9	0287-881-079	Insufficient Sample	Insufficient Sample	Insufficient Sample
6486	64-86-07-16-87	07/16/87	Routine	8.50	867	20.8	0387-881-039	0387-881-044	0387-881-048	Insufficient Sample
6486	DRY	10/12/87								

Table 5-7 (cont.)

GROUND WATER SAMPLE INFORMATION

ALLUVIAL WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS			
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	METALS	INORGANICS	RADIOCHEMISTRY
6586	G658609860	09/19/86	Routine	6.90	1500	19.0	8609-051-036	8609-051-037	8609-051-038	1000-000-302
6586	G658609862	09/19/86	Field Duplicate	7.00	1200	19.0	8609-051-046	8609-051-047	8609-051-048	1000-000-304
6586	65-86-05-13-87	05/13/87	Routine	7.20	998	12.8	0187-881-090	0187-881-090	0187-881-100	0187-881-102
6586	65-86-05-28-87	05/28/87	Routine	7.70	775	14.9	0287-881-020	0287-881-020	0287-881-020	0287-881-020
6586	65-86-07-16-87	07/16/87	Routine	6.80	744	21.3	0387-881-040	Insufficient Sample	Insufficient Sample	Insufficient Sample
6586	65-86-09-08-87	09/08/87	Routine	7.80	920	19.9	0387-881-109	0387-881-116	0387-881-110	0387-881-093
6586	DRY	10/19/87								
6686	DRY	09/25/86								
6686	66-86-05-11-87	05/11/87	Routine	7.30	269	11.2	0187-881-084	0187-881-084	0187-881-086	0187-881-087
6686	66-86-05-28-87	05/28/87	Routine	7.40	386	14.7	0287-881-018	0287-881-018	0287-881-021	0287-881-018
6686	DRY	07/17/87								
6886	G688609860	09/22/86	Routine	6.70	332	15.0	8609-056-0060	8609-056-007	8609-056-008	1000-000-308
6886	68-86-04-29-87	04/29/87	Routine	6.80	210	9.0	0187-881-066	0187-881-066	0187-881-067	0187-881-067
6886	68-86-05-28-87	05/28/87	Routine	7.20	280	15.3	0287-881-019	0287-881-019	0287-881-022	0287-881-019
6886	68-86-07-14-87	07/14/87	Routine	6.90	345	19.6	0387-881-036	0387-881-146	0387-881-044	0387-881-017
6986	G698610860	10/08/86	Routine	6.90	1900	14.5	8610-028-0060	8610-028-007	8610-028-008	1000-000-309
6986	G698610862	10/08/86	Field Duplicate	7.80	1900	14.5	8610-028-0160	8610-028-017	8610-028-018	1000-000-311
6986	69-86-04-29-87	04/29/87	Routine	7.00	1500	10.0	0187-881-064	0187-881-064	0187-881-066	0187-881-066
6986	69-86-05-26-87	05/26/87	Routine	7.10	1398	12.2	0287-881-010	0287-881-008	0287-881-008	0287-881-008
6986	69-86-07-06-87	07/06/87	Routine	7.10	1228	17.1	0387-881-023	0387-881-025	0387-881-032	0387-881-110
6986	69-86-10-07-87	10/07/87	Routine	6.20	1099	15.4	0487-881-012	0487-881-015	0487-881-012	0487-881-008
6986	69-86-10-08-87	10/08/87	Field Split				No Sample	No Sample	No Sample	0187-123-014

Table 5-8

GROUND WATER SAMPLE INFORMATION

BEDROCK WELLS

WELL NUMBER	SAMPLE INFORMATION NUMBER	DATE	TYPE	FIELD PARAMETERS pH	CONDUCT (umho/cm)	TEMP (deg C)	LABORATORY BATCH NUMBERS VOLATILE ORGANICS	METALS	INORGANICS	RADIOCHEMISTRY
0387	GW0387	06/16/87	Field Split	8.10	740	14.0	8706-042-0100	No Sample	No Sample	No Sample
0387	3-87-06-16-87	06/16/87	Routine				0587-881-005	0587-881-005	0587-881-005	0587-881-005
0387	3-87-07-08-87	07/08/87	Routine	8.40	832	14.1	0387-881-026	0387-881-138	0387-881-037	0387-881-009
0387	3-87-10-05-87	10/05/87	Routine	7.40	687	14.5	0687-881-011	0687-881-010	0687-881-011	0687-881-010
0387	3-87-10-05-87	10/05/87	Field Split				8710-017-0030	No Sample	No Sample	No Sample
0587	GW0587	06/11/87	Field Split	6.90	2170	14.0	8706-037-0010	No Sample	No Sample	No Sample
0587	5-87-06-12-87	06/12/87	Routine				0587-881-003	0587-881-003	0587-881-003	0587-881-003
0587	5-87-07-06-87	07/06/87	Routine	6.90	1990	13.3	0387-881-020	0387-881-023	0387-881-029	0387-881-109
0587	5-87-10-12-87	10/12/87	Routine	6.90	2170	14.0	0687-881-014	0687-881-014	0687-881-015	0687-881-014
0587	5-87-10-12-87	10/12/87	Field Split				8710-041-0020	No Sample	No Sample	No Sample
0887	GW0887	06/13/87	Field Split	8.40	1488	13.8	8706-042-0090	No Sample	No Sample	No Sample
0887	8-87-06-15-87	06/15/87	Routine				0587-881-004	0587-881-004	0587-881-004	0587-881-004
0887	8-87-07-08-87	07/08/87	Routine	7.40	2100	14.3	0387-881-028	0387-881-140	0387-881-039	0387-881-012
0887	8-87-10-07-87	10/07/87	Routine	8.40	1488	13.8	0687-881-012	Insufficient Sample	Insufficient Sample	Insufficient Sample
4587	45-87-11-23-87	11/23/87	Field Split				8711-063-0001	No Sample	No Sample	No Sample
4587	45-87-11-24-87	11/24/87	Routine	7.90	288	12.1	0487-881-047	0487-881-081	0487-881-085	0487-881-011
5986	G598610860	10/08/86	Routine	7.20	1600	13.5	8610-028-0210	8610-028-22	8610-028-023	Insufficient Sample
5986	59-86-04-09-87	04/09/87	Routine	7.00	1350	10.0	0187-881-043	0187-881-043	0187-881-046	0187-881-046
5986	59-86-04-30-87	04/30/87	Routine	7.10	1330	12.0	0187-881-067	0187-881-067	0187-881-071	0187-881-071
5986	59-86-05-26-87	05/26/87	Routine	7.20	1804	12.1	0287-881-008	0287-881-010	0287-881-010	0287-881-010
5986	59-86-07-06-87	07/06/87	Routine	7.20	1396	14.3	0387-881-024	0387-881-132	0387-881-030	0387-881-112
5986	59-86-10-07-87	10/07/87	Routine				0487-881-011	0487-881-014	0487-881-011	
6286	G628610860	10/16/86	Routine	10.40	560	13.5	8610-044-0260	8610-044-27	8610-044-028	Insufficient Sample
6286	62-86-04-09-87	04/09/87	Routine	9.40	510	13.0	0187-881-044	0187-881-044	0187-881-047	0187-881-047
6286	62-86-04-29-87	04/29/87	Routine	9.30	500	13.0	0187-881-068	0187-881-068	0187-881-069	0187-881-069
6286	62-86-05-26-87	05/26/87	Routine	8.90	447	12.6	0287-881-009	0287-881-009	0287-881-009	0287-881-009
6286	62-86-07-06-87	07/06/87	Routine	9.20	359	14.4	0387-881-021	0387-881-024	0387-881-031	0387-881-113
6286	62-86-10-14-87	10/14/87	Routine	9.90	408	13.8	0487-881-017	0487-881-022	0487-881-018	0487-881-009

5.4.1 Background Ground-Water Quality

Background ground-water quality is established in this section based on data from three alluvial/bedrock well pairs west of the plant (46-86BR/47-86, 51-86/52-86BR, and 54-86BR/55-86). In addition, data from alluvial wells 10-81, 49-86, 50-86, and 56-86 are evaluated to increase the size of the background database; however, these wells are downgradient of the West Spray Field (SWMU 168) or downgradient of the Ash Pits (SWMU 133) and some judgement is required to use these data to characterize background conditions.

Background conditions are characterized in this document as concentration ranges. The analytical results have been examined for consistency over time at each well and between wells. If a result is inconsistent in magnitude with other results from the well or other wells, it is excluded from consideration in developing the background range. The outlier values may be due to laboratory error in analysis or field contamination of the samples; however, they could also be natural concentration variations. The exclusion of high-valued outliers from the background characterization results in a conservative comparison between background and downgradient conditions.

5.4.1.1 Background Alluvial Ground-Water Quality

Alluvial ground water west of the plant is of excellent quality, characterized by low concentrations of major ions, metals and radionuclides. Organic compounds are non-detectable and pH ranges from 6.0 to 7.4. Analytical data are presented in

Appendix F, and a summary of the determined background ranges is presented in Table 5-9.

Major Ions

Total dissolved solids (TDS) concentrations, an indicator of dissolved major ion content, are generally low in the background alluvial ground water (ranging from 113 to 309 mg/l). Concentrations of specific cations and anions that make up the majority of the TDS are as follows.

Cations

1) Calcium concentrations were consistent in all of the wells, ranging from 12 to 36 mg/l.

2) Magnesium concentrations were also fairly stable, in the range of 2 to 8 mg/l.

3) Sodium concentrations ranged from 8 to 21 mg/l in the wells, with the exception of samples from 49-86 which ranged from 21 to 36 mg/l.

4) Potassium is generally less than the detection limit of 0.01 mg/l but was detected in one sample from 55-86 at 5 mg/l. Because the highest detection in the background wells is so low, the entire range of less than 0.01 to 5 mg/l is presented on Table 5-9.

Anions

1) Sulfate concentrations ranged from less than 1 to 27 mg/l.

2) Chloride concentrations ranged from 0.7 to 20 mg/l in most of the samples. Samples from well 49-86 were slightly higher, in the range of 24 to 31 mg/l and one sample from well 10-81 had a concentration of 444 mg/l. These are considered outliers.

3) Bicarbonate and carbonate ranged from non-detectable to 130 mg/l and 120 mg/l for bicarbonate and carbonate, respectively. Given the pH ranges presented above, any carbonate is considered abnormal. Therefore, appropriate background concentrations are considered to be non-detectable to 130 mg/l and non-detectable for bicarbonate and carbonate, respectively.

TABLE 5-9
BACKGROUND ALLUVIAL
GROUND-WATER QUALITY

METALS

Element	Concentration Range (mg/l)
Antimony	.060U
Arsenic	.001U
Barium	.047-.190
Beryllium	.007
Cadmium	.007
Cesium	.1U
Chromium	.002U-.046
Cobalt	.05U
Copper	.02U-.046
Lead	.005U-.05
Manganese	.01U-.547
Mercury	.0002U
Molybdenum	.1U
Nickel	.04U-.07
Selenium	.005U
Silver	.01U
Strontium	0.02U-.20
Thallium	.01U
Vanadium	.005U-.047
Zinc	.005U-0.09

RADIONUCLIDES

Plutonium, Americium, Uranium-235	Non-detected
Uranium-234	Non-detected - 3.5(.9)
Uranium-238	Non-detected - 5.5(2.1)

MAJOR IONS

Ion	Concentration Range (mg/l)
Calcium	12-36
Magnesium	2-8
Potassium	.01U-5
Sodium	8-21
Bicarbonate	ND-130
Carbonate	ND-120
Chloride	.7-20
Nitrate	ND-1.5
Sulfate	1U-31
Total Dissolved Solids	113-309

4) Nitrate concentrations ranged from non-detectable to 1.5 mg/l in samples from well 55-86. Many of the samples from the wells included in the background evaluation to increase the size of the database (10-81, 49-86, 50-86, and 56-86) had concentrations that exceed this range and they were excluded as outliers.

Based on these generalized ranges, the major ion chemistry of background alluvial ground water is dominated by calcium and sodium among the cations and bicarbonate among the anions.

Metals

Metal concentrations are generally low in the alluvial ground water west of the plant. Of the twenty metals for which analyses were made, eight were either not detected or detected at concentrations below the Contract Laboratory Program (CLP) required detection limits. The non-detected metals, together with the CLP detection limits, are:

1. antimony (0.06 mg/l),
2. arsenic (0.01 mg/l),
3. cesium (0.1 mg/l),
4. cobalt (0.05 mg/l),
5. molybdenum (0.1 mg/l),
6. selenium (0.005 mg/l),
7. silver (0.01 mg/l), and
8. thallium (0.01 mg/l).

For these metals, the CLP detection limits are considered the maximum reasonable values for background conditions.

The CLP detection limits for beryllium (0.005 mg/l) and mercury (0.0002 mg/l) are also considered the maximum reasonable values for background conditions, although each of these metals was detected once in separate samples. The detections (0.011 mg/l beryllium and 0.003 mg/l mercury) are considered outliers and were excluded from the background range.

The other ten metals were detected in enough samples that a background range can be established, as follows.

1. Barium was consistently detected in the range of 0.047 to 0.19 mg/l.

2. Cadmium was detected twice at concentrations above the CLP detection limit of 0.005 mg/l (0.006 mg/l in a sample from well 51-86 and 0.007 mg/l in a sample from well 47-86). These wells are considered reliable background wells and 0.007 mg/l has been used as the upper limit of the background range.

3. Chromium concentrations were generally less than the CLP detection limit of 0.002 mg/l; however, several spatially and temporally unrelated samples contained concentrations ranging from 0.009 to 0.136 mg/l. The highest concentration of 0.136 mg/l is considered an outlier because it is approximately an order of magnitude higher than the next highest concentration (0.027 mg/l). Thus, the background range is considered to be less than the detection limit of 0.002 to 0.027 mg/l.

4. Copper concentrations were less than the CLP detection limit of 0.02 mg/l in all samples except one, in which the concentration was 0.046 mg/l. Because the detected value is within an order of magnitude of the rest of the values, the higher value is included in the background range of less than 0.02 to 0.046 mg/l.

5. Lead was generally not detected above the CLP detection limit of 0.005 mg/l; however, a few samples yielded values in the range of 0.01 to 0.05 mg/l. Because the detected values are within an order of magnitude of the rest of the values and neither a temporal nor spatial trend is apparent in the data, the higher values have been included in the background range of less than 0.005 to 0.05 mg/l.

6. Manganese concentrations varied from below the CLP detection limit of 0.01 mg/l to a maximum concentration of 0.55 mg/l. Because an early sample from well 55-86 yielded the highest result (and 55-86 is considered a reliable background well), the entire range of detected concentrations is considered reasonable for background conditions.

7. Nickel was generally not detected above the CLP detection limit of 0.04 mg/l. The two detections in samples from different wells (0.03 and 0.07 mg/l) are so close to the detection limit that they are considered reasonable for background conditions.

8. Strontium concentrations ranged from below the CLP detection limit of 0.02 mg/l to a maximum concentration of 0.20 mg/l. Because concentrations in samples from well 55-86 ranged from 0.11 to 0.15 mg/l (near the maximum of the range of all samples) and well 55-86 is considered to be a reliable background well, the entire range of detected concentrations is considered reasonable for background conditions.

9. Vanadium was generally not detected above the CLP detection limit of 0.005 mg/l; however, there were four spatially and temporally unrelated detections of ranging from 0.024 to 0.047 mg/l. Because the detections are unrelated and within an order of magnitude of most of the values, a range of less than 0.005 to 0.047 mg/l is considerable reasonable for background conditions.

10. Zinc concentrations were usually greater than the CLP detection limit of 0.005 mg/l, generally in the range of 0.02 to 0.09 mg/l. In addition, there were two values of 0.185 and 0.49 mg/l that are considered outliers. The range of less than 0.005 to 0.09 mg/l is considered reasonable for background conditions.

Radionuclides

Background alluvial ground water contains low concentrations of radionuclides. Plutonium, americium, and uranium-235 concentrations generally have uncertainties associated with the determination that are on the order of the determination itself. Uncertainty arises in radiometrically determined concentrations because radioactive decay (the measured parameter) is a random process. The reported value is an estimate of the mean value that could be developed from the range of values obtained from repeated measurements on the same sample. The uncertainties reported in this work are equivalent to 2 standard deviations about the estimate of the mean, i.e., the true value is in a band defined by the estimated mean, plus or minus the uncertainty, to a confidence of approximately 95 percent. Radiometrically determined concentrations with uncertainties equal to or greater than the estimate of the mean are similar to non-detectable concentrations of non-radioactive parameters because the concentration is not really quantifiable at the reported mean level. However, the determination differs from the more standard result in that the determination allows the analyst to establish confidence limits about the true mean; i.e., the true mean is somewhere between the reported mean less the uncertainty (zero in the situation under discussion) and the reported mean plus the uncertainty. Therefore, although the determined concentrations of plutonium, americium, and uranium-235 appear to approach 0 pCi/l, additional determinations can be expected to fall in the range between zero and the average of the background uncertainties; about 0.6 pCi/l for plutonium and americium, and about 0.4 pCi/l for uranium-235, based on data in Appendix F-2.

Uranium-234 and uranium-238 were fairly frequently determined at concentrations exceeding the associated uncertainties. The October 1986 radiometric results are generally higher and have smaller uncertainties than data developed during the first three quarters of 1987. The sum of uranium-234 and -238 activities determined in 1986 ranged from 0.59 to 14 pCi/l with uncertainties of 10 to 15% of the mean. Data developed in 1987 contain many more values with associated uncertainties on the order of the value, and the reported values are generally somewhat lower than the 1986 data. Means reported in 1987 were as high as 3.5 pCi/l for uranium-234 and 5.5 pCi/l for uranium-238, implying that isotopic sums in the range of 0 to about 9 pCi/l are considered reasonable for background chemical conditions during 1987. However, the data collected in 1986 suggest that the values may vary from year to year based on natural geochemical variability. Therefore, as a database is developed over time, the background range may increase.

5.4.1.2 Background Bedrock Ground-Water Quality

Ground water in the bedrock west of the plant is of excellent quality, characterized by low concentrations of major ions, metals and radionuclides. Organic compounds are non-detectable and pH ranges from 6.5 to 10.6. Analytical data are presented in Appendix F, and a summary of the determined background ranges is presented in Table 5-10.

TABLE 5-10

BACKGROUND BEDROCK
GROUND-WATER QUALITY

METALS

Element	Concentration Range (mg/l)
Antimony	.06U
Arsenic	.001U
Barium	.04-.22
Beryllium	.005U
Cadmium	.005U
Cesium	.1U
Chromium	.002U-.015
Cobalt	.05U
Copper	.02U-.05
Lead	.005U-.030
Manganese	.01-.23
Mercury	.0002U-.0003
Molybdenum	.1U
Nickel	.04U
Selenium	.002U
Silver	.01U
Strontium	.14-.87
Thallium	.002U
Vanadium	.005U-.05
Zinc	.005U-.09

RADIONUCLIDES

Plutonium, Americium, Uranium-235	Not detected
Uranium-234	Not detected - 6.6(1.8)
Uranium-238	Not detected - 7.5(1.7)

MAJOR IONS

Ion	Concentration Range (mg/l)
Calcium	7-110
Magnesium	1-25
Potassium	1-8
Sodium	22-47
Bicarbonate	9-318
Carbonate	ND-257
Chloride	1-24
Nitrate	ND
Sulfate	ND-66

Major Ions

Total dissolved solids, an indicator of major ion concentrations, are generally low in background bedrock ground water (ranging from approximately 125 to 425 mg/l). The ranges of reasonable background major ion concentrations include all determinations on samples from wells 46-86BR, 52-86BR and 54-86BR, because the results were uniformly distributed over the ranges. The only exception is that the single detection of nitrate at 18.4 mg/l was excluded from consideration as an outlier The concentration ranges presented in Table 5-10 indicate that the major ion chemistry of background bedrock ground water is dominated by calcium and bicarbonate. The pH determinations in excess of 8.3 and associated carbonate detections may be produced by well completion materials.

Metals

Metal concentrations in the bedrock ground water are generally low. Eleven of the twenty metals for which analyses are made were not detected above the CLP detection limits:

1. antimony,
2. arsenic,
3. beryllium,
4. cadmium,
5. cesium,
6. cobalt,
7. molybdenum,
8. nickel,
9. selenium,
10. silver, and
11. thallium.

The CLP detection limits are considered the maximum reasonable values for background conditions.

Background ranges were established for the other nine metals as follows.

1. Barium concentrations varied uniformly between 0.04 mg/l and 0.23 mg/l; the entire range is considered reasonable for background conditions.

2. Chromium was generally not detected above the CLP detection limit of 0.002 mg/l; however, the maximum detected value (0.015 mg/l) is within an order of magnitude of the detection limit and is therefore included in the range of reasonable background values.

3. Copper concentrations were generally in the range 0.01 to 0.05 mg/l. In addition, there was a single result of 0.132 mg/l, which was excluded from the background range as an outlier.

4. Lead was generally not detected above the CLP detection limit of 0.005 mg/l; however, the maximum detected value (0.03 mg/l) is within an order of magnitude of the detection limit and is therefore included in the range of reasonable background values.

5. Manganese concentrations varied from below the CLP detection limit of 0.01 mg/l to 0.23 mg/l. Because of the uniformity of the distribution within the range, the entire range is considered reasonable for background conditions.

6. Mercury was generally not detected above the CLP detection limit of 0.0002 mg/l; however, the maximum detection of 0.0003 mg/l is within an order of magnitude of the detection limit and is therefore included in the range of reasonable background values.

7. Strontium concentrations varied uniformly between 0.14 mg/l and 0.87 mg/l; the entire range is considered reasonable for background conditions.

8. Vanadium was generally not detected above the CLP detection limit of 0.005 mg/l; however, the maximum detected value (0.05 mg/l) is an order of magnitude of the detection limit and is therefore included in the range of reasonable background values.

9. Zinc was generally not detected above the CLP detection limit of 0.005 mg/l; however, the maximum detected value (0.09 mg/l) is almost within an order of magnitude of the detection limit and is therefore included in the range of reasonable background values.

Radionuclides

Background bedrock ground water contains low concentrations of radionuclides. Plutonium, americium, and uranium-235 concentrations generally have uncertainties associated with the determination that are on the order of the determination itself. As discussed earlier, this is similar to non-detectable concentrations of other parameters.

Both uranium-234 and -238 were fairly regularly determined at concentrations exceeding the associated uncertainty. Uranium-234 determinations were in the range of 0.19 ± 0.16 to 6.6 ± 1.8 pCi/l, and uranium-238 determinations were in the range of 0.14 ± 0.03 to 7.5 ± 1.7 pCi/l. Therefore, concentrations of uranium-234 below 6.6 ± 1.8 and uranium-238 below about 7.5 ± 2 pCi/l are considered reasonable for background chemical conditions.

5.4.2 881 Hillside Ground-Water Chemistry

Volatile organic compounds (VOCs) have been detected in shallow ground water in two spatially distinct portions of the 881 Hillside. In addition, there are apparently elevated concentrations of uranium, selenium, nickel, strontium and major ions in shallow ground water that may be related to activities at the 881 Hillside SWMUs or to natural geochemical variability. Ground water in the bedrock does not appear to be impacted by the activities at the SWMUs.

The elevated concentrations of these constituents occur in two general portions of the 881 Hillside: the area immediately south of Building 881 (SWMUs 103, 106, and

107) and the area near SWMU 119.1. Therefore, this section is divided into two subsections discussing chemical conditions in each area.

5.4.2.1 SWMUs 103, 106, and 107

Occurrence and Flow of Ground Water

Ground water occurs in both surficial materials and bedrock in the vicinity of SWMUs 103, 106, and 107. Details of the stratigraphy are presented in cross sections A-A', B-B', and C-C'. Most of the surficial materials are clayey soils consisting of natural colluvium or reworked bedrock, colluvium, and Rocky Flats Alluvium from the excavation for construction of Building 881. There is a thin gravel in undisturbed colluvium in the vicinity of the three well cluster (69-86, 59-86BR and 8-87BR). In addition, there is a different gravel layer immediately south of Building 881 that is probably imported material used for pavement base and bedding around buried utilities.

The flow of water in the surficial materials is probably both slow and of small quantity because of the discontinous nature of the various materials and their low hydraulic conductivity. The potentiometric surface maps presented in Plates 5-5 through 5-7 indicate some seasonal variability of potentiometric conditions, but not enough to change the general flow pattern toward the footing drain and Woman Creek. In addition, the very high water level in well 2-87 implies recharge of the shallow ground-water system from the skimming pond. The source of the ground water includes incident precipitation but is probably dominated by water diverted from the Rocky Flats Alluvium by the footing drain. The ground water discharges to the South Interceptor Ditch, to evapotranspiration and probably to the valley fill alluvium. In addition, there is also some flow through claystone bedrock to the underlying permeable horizons.

Description of Chemical Conditions

Chemical conditions have been investigated by installing an upgradient well (1-87) and six shallow wells near and downgradient from the SWMUs. In addition, three bedrock wells were installed in the shallowest permeable zones in the bedrock in areas considered most likely to be contaminated if bedrock contamination is present (3-87BR, 59-86BR and 8-87BR). Samples have been obtained from three of the shallow downgradient wells and all of the bedrock wells. Samples have not been obtained from the upgradient well and three of the shallow wells because of unsaturated conditions in the surficial materials (supporting the conclusion that there is only a limited quantity of ground water in the vicinity). The chemical results are discussed below.

The major ion chemistry in the ground water is quite diverse and distinctly different from background. TDS concentrations range from about 425 to 1200 mg/l and the major ion chemistry is generally dominated by sodium (or sodium and calcium) among the cations and bicarbonate, sulfate or bicarbonate and sulfate among the anions. Major ion chemistry is very similar in shallow ground water and bedrock ground water at well pairs 2-87/3-87BR (sodium-bicarbonate water with TDS of about 500 mg/l) and 69-86/59-86BR (sodium-calcium-bicarbonate water with TDS of about 900 mg/l). However, major ion chemistries are distinctly different between permeable zones in the bedrock at 59-86BR (sodium-calcium-bicarbonate water with TDS of about 900 mg/l) and at 8-87BR (sodium-sulfate water with TDS of about 1200 mg/l). The distinct difference between these waters indicates that there is probably little communication between these bedrock zones, even though the difference is manifested by poorer quality water in the deeper zone.

Metal concentrations are generally similar to background conditions with the exception of selenium and strontium. Selenium was detected in the shallow ground water in samples from 69-86 at about 0.2 mg/l and strontium was detected in shallow ground water in samples from 2-87, 52-87, and 69-86 at concentrations ranging from 0.4 to about 1 mg/l. Selenium and strontium were also detected in samples of bedrock ground water; selenium in samples from 59-86BR at concentrations of approximately 0.1 mg/l, and strontium in samples from 59-86BR, 3-87BR and 8-87BR at concentrations ranging from about 0.4 to 1.4 mg/l. The selenium detections are both from the three well cluster (surficial and most-shallow bedrock ground water but not deeper bedrock ground water) and strontium was detected in every sample (both shallow and bedrock ground water).

Most of the radiometrically determined compounds are within the range of background concentrations except for the uranium isotopes. The sum of the estimated means for uranium-234 and uranium-238 concentrations in shallow ground water ranges from about 17 pCi/l in samples from wells 2-87 and 69-86 to 36 pCi/l in the only sample from well 52-87, with uncertainties of about 10% of the means. Concentrations are approximately 25 pCi/l in bedrock ground-water samples from well 59-86BR, but are within the background range in samples from the other bedrock wells. Elevated uranium isotopes are ubiquitous in the shallow ground water near Building 881 and appear higher near to the building. Elevated uranium is also indicated in the most-shallow ground water at the three well cluster, but at concentrations higher than found in samples from the immediately-overlying ground water in surficial materials.

Volatile organic compounds are generally non-detectable in the both the shallow and bedrock ground water with the exception of the only sample from well 53-87 completed in surficial materials near Building 881. Detected concentrations were on the order of 20 ug/l of methylene chloride, 1,1-DCE, TCA, and TCE. Carbon tetrachloride and toluene were also detected but at low concentrations.

The source of these elevated compounds may be the 881 footing drain. The 881 footing drain flow (SW-45 and FDRAIN in the database) has a TDS of approximately 500 mg/l and is a calcium-bicarbonate water. These characteristics help but do not perfectly explain the higher TDS concentrations in the shallow well downgradient of the skimming pond and the dominance of calcium among some of the shallow and bedrock wells. The footing drain also contains elevated concentrations of strontium (about 0.6 mg/l) and had detectable selenium in one of the two analyses. However, uranium isotopes are within the general range of background (approximately 10 pCi/l with an uncertainty of about 35 percent). The footing drain flow also consistently contains low concentrations of TCE (8-14 ug/l) and PCE (16-128 ug/l) and may also contain methylene chloride, carbon tetrachloride and toluene. In addition, the flow contains dissolved nitrate concentrations of 8.5 mg/l as nitrogen. Therefore, the footing drain flow is not the only source of charged ground water chemistry.

Summary and Conclusions

Chemical conditions in ground water are distinctly different from plant background conditions. These differences and implications of them are as follows.

1. Major ion chemistry indicates dominance by sodium and bicarbonate downgradient of the skimming pond in both shallow and bedrock ground water. The quality of this water is not necessarily unacceptable; TDS is approximately 500 mg/l. Vertical gradient calculations indicate

continuous saturation between the shallow system and the bedrock system at this location; chemical data also suggest continuity between these systems.

2. Major ion chemistry indicates dominance by sodium, calcium and bicarbonate in the shallow and uppermost bedrock ground water in the vicinity of the three well cluster. The major ion chemistry in the deeper ground water at this location is different from the more shallow ground waters, indicating poor connection with the deeper ground water, but possibly fairly good connection between the shallow ground water and the uppermost bedrock ground water.

3. Metal concentrations are generally similar to background conditions except for elevated selenium and strontium.

   Selenium was only detected in samples from the shallow and uppermost bedrock ground water at the three well cluster, supporting the conclusion that these waters are interconnected but separate from the deeper bedrock ground water. Because the uppermost bedrock ground water zone is not connected by continuously saturated material to the shallow ground water (the well even becomes dry on occasion), it is concluded that the uppermost bedrock flow zone is recharged at a subcrop slightly west of the location of the cluster. Selenium concentrations were in the range of 0.1 to 0.2 mg/l, well within the range of values reported by Moran (1976) as naturally occuring in the Golden area.

   Strontium was detected in samples from all of the wells near Building 881, even in wells with demonstrably poor connection with the shallow ground-water system. Because strontium was found in samples from all of the wells, it is concluded that its occurrence is the result of a different geochemical environment, rather than a release from one of the SWMUs. In addition, the strontium detected is not the radioactive isotope, for which analyses were also made in early 1987. Strontium concentrations are in the range of 0.4 to 1.4 mg/l much lower than concentrations in several drinking water supplies reported in Hem (1985).

4. Radionuclide concentrations are generally equivalent to background concentrations except for the uranium isotopes. The sum of the uranium-234 and uranium-238 concentrations is approximately 36 pCi/l in shallow ground water near Building 881, approximately 25 pCi/l in the uppermost bedrock ground water at the three well cluster and approximately 17 pCi/l in shallow ground water at the three well cluster and at the downstream end of the skimming pond. These findings are significant in that:

   a. the source may be in the vicinity of well 52-87,
   b. the subcrop feeding the uppermost bedrock ground water at the three well cluster is probably located between the cluster and the Building, and

c. most significantly, bedrock ground water at the end of the skimming pond (well 3-87BR) does not contain elevated uranium which implies that it is in poor connection with the overlying shallow ground water that does contain elevated uranium.

Although uranium concentrations are elevated with respect to conditions west of the plant, they are actually quite low (less than the proposed drinking water standard of 40 pCi/l). In addition, based on isotopic ratios, the dissolved uranium is probably of natural origin and does not represent a release of the uranium used in plant processes.

5. Volatile organic compounds are generally non-detectable in ground water near Building 881 except for the single sample of shallow ground water from well 53-87.

In conclusion, there can be little doubt that the discharge from the footing drain is recharging shallow ground water on the slope below Building 881 and that the footing drain flow is of poor quality. However, the footing drain flow does not fully explain the elevated TDS concentrations, changed major ion chemistry nor the elevated uranium isotopes in the general area. Therefore, it is concluded that these changes are the result of other sources in the general area. One of these may be contaminated soils near Building 881 (near well 53-87). In addition, the elevated but natural constituents (major ions, selenium, strontium and uranium) may be representative of the geochemical environment of the colluvium mantling the slope. This is entirely possible given that background data have not been collected from this environment.

5.4.2.2 SWMU 119.1

Occurrence and Flow of Ground Water

Ground water occurs in both surficial materials and bedrock in the vicinity of SWMU 119.1. Details of the stratigraphy are presented in cross sections D, E, F, G and H. Most of the surficial materials are clayey soils consisting of natural or slightly disturbed colluvium. The colluvium includes several thin but discrete gravel lenses that may be continuous in the downslope direction but are clearly discontinuous perpendicular to the slope. The stratigraphy along the most crucial alignment is shown with 5-times vertical exaggeration in cross section E in order to show the hypothesized continuity of the gravel lenses. The surficial materials are directly underlain by claystones of the Arapahoe Formation.

The topography in the vicinity of the SWMU is slightly bowl shaped with minor ridges running down the slope. The ridges are capped with sandy or gravelly materials (e.g., 50-87) which may be remnants of gravel lenses in the colluvium. The topography is believed to result from erosional processes.

The flow of ground water in the surficial materials is probably slow (except possibly in the gravel lenses) and of small quantity. The surficial materials are recharged primarily by infiltration. Saturated conditions appear restricted to an area centered around well 9-74 in a surficial and structural trough (section H) and this is believed to result from channeling of recharge from the small surface water drainage basin toward the SWMU on top of low permeability bedrock. The surficial materials may also be recharged by flow from permeable zones in the bedrock subcropping near the crest of the slope. The seep located east of the SWMU is hypothesized to derive its flow from this mechanism. The Rocky Flats Alluvium is dry upslope of the area and therefore does not provide recharge.

Flow in the surficial materials is in the downslope direction. The potentiometric surface maps presented on Plates 5-5 through 5-7 indicate some seasonal variations of potentiometric conditions but not enough to change the general flow pattern. The detailed cross section oriented in the downslope direction (Section

E) shows a fairly mild gradient in the gravel lenses that steepens downslope where the gravels have pinched-out. The steeper gradient is required to move a constant flow through the lower permeability materials. Thus, ground water is believed to discharge from the colluvium into the valley fill alluvium, although the quantity is probably small because of the low permeability of most of the colluvium. Discharge may also occur to the Interceptor Ditch during very wet periods and there is probably a small discharge to evaporation. In addition, there is probably also some flow through claystone bedrock to the underlying permeable horizons.

Description of Chemical Conditions

Chemical conditions have been investigated by installing a shallow well in the center of the SWMU and six shallow wells downgradient. In addition, a bedrock well was installed in the shallowest permeable zone in the bedrock in the area considered most likely to be contaminated if bedrock contamination is present. An attempt was also made to install a shallow well upgradient of the SWMU but saturated conditions were not encountered. Complete samples have been obtained from the bedrock well and three of the shallow wells. Volatile organic analyses are available for all of the wells except shallow well 49-87 which was dry. The chemical results are discussed below.

The major ion chemistry in the vicinity of SWMU 119.1 is diverse and distinctly different from background conditions. In addition, it is distinctly different from the major ion chemistry in the vicinity of Building 881. TDS concentrations range from about 1200 mg/l in samples from shallow wells 43-87 (in center of SWMU) and 6-87 to about 1750 mg/l in samples from shallow well 4-87 (downgradient of 43-87). TDS concentrations in samples from bedrock well 5-87BR (near 43-87) are about 1500 mg/l. The major ion chemistry is generally dominated equally by both calcium and sodium among the cations (calcium dominates in samples from bedrock well 5-87BR) and about equally dominated by chloride, sulfate and bicarbonate. In addition, samples from bedrock well 5-87BR contain dissolved potassium of approximately 11 mg/l. The different major ion chemistry in samples from bedrock well 5-87BR indicates poor connection between the shallow and bedrock ground-water systems at the SWMU. This is supported by the lack of continuous saturation between the systems evidenced by the vertical gradient of 1.25 calculated between wells 43-87 and 5-87BR (Table 5-3).

Metal concentrations are generally consistent with background concentrations except for nickel, selenium and strontium. The distribution of these metals is discussed below.

1. Nickel was found in samples from all of the shallow ground-water wells at concentration of approximately 0.2 mg/l but was not detected in the bedrock ground water.

2. Selenium concentrations vary in space but are fairly consistent in repeated samples at the wells. In the shallow ground water, selenium was found at about 0.5 mg/l in the sample from 43-87, at about 0.2 mg/l in samples from 4-87 and at 0.02 mg/l in the sample from 6-87. Selenium was found at about 0.05 mg/l in the samples from the bedrock well 5-87BR. The selenium concentration in the sample from 43-87 is the highest detected in the investigation and may indicate that the SWMU is the source of the selenium in the immediate vicinity. The lower concentrations downgradient may indicate attenuation processes.

3. Strontium was found at concentrations ranging from about 1 to 2 mg/l in samples of shallow ground water and about 3 mg/l in the sample from bedrock well 5-87BR.

Radiometric concentrations are generally consistent with background conditions except for the uranium isotopes. The sum of the estimates of the means of uranium-234 and uranium-238 is 37 pCi/l in the sample from well 43-87 (center of the SWMU), 36 pCi/l in samples from 4-87 and 55 pCi/l in the sample from well 6-87 (all completed in shallow ground water and with uncertainties of about 20 percent). Concentrations in samples from bedrock well 5-87BR are about 18 pCi/l with an uncertainty of about 20 percent, which may be within the range of background bedrock ground-water concentrations. Considering the uncertainties, the concentrations in shallow ground water are about equal, but the concentration in bedrock ground water is lower than in the shallow ground water.

Volatile organic concentrations are quite high at the center of the SWMU. Samples of shallow ground water from wells 9-74 and 43-87 have the highest VOC concentrations and data for the VOCs occurring at concentrations greater than 1000 ug/l are summarized below:

VOC	Concentration (ug/l) 9-74	Concentration (ug/l) 43-87*
1,1-DCE	703-48,000	32,687
1,1,1-TCA	4U-30,250	12,734
trans-1,2-DCE	5U	5,070
CCl_4	4U-28,000	2,170
TCE	11,000-72,000	6,999
PCE	2,400-13,200	4,259

* Sample collected 12/17/87.

Volatile organics have also been detected in samples from 10-74 (although this well is often dry) and in samples from 4-87 and 6-87. Concentrations in samples from 10-74 are highly variable, but carbon tetrachloride and TCE are always detected at concentrations ranging from 400 to 1400 ug/l and 300 to 3600 ug/l, respectively. Concentrations in samples from 4-87 are much lower, on the order of 10 and 50 ug/l for the same compounds. In addition, PCE is fairly routinely detected in samples from 4-87. Concentrations in samples from 6-87 are also rather low; only TCE has been detected at concentrations of about 20 ug/l. Volatile organic compounds have not been detected in the next-downgradient shallow ground-water wells: 47-87, 48-87 and 55-87. In addition, volatiles are below detection limits in the bedrock ground-water samples from 5-87BR. Based on these considerations, it is concluded that the extent of volatile organic contamination of shallow ground water has been delineated and that there is no volatile organic contamination of the bedrock ground water.

Summary and Conclusions

Chemical conditions in ground water are distinctly different from plant background conditions. These differences and implications of them are as follows.

1. The major ion chemistry is distinctly different from plant background. The shallow ground water is about equally dominated by calcium, sodium, chloride, sulfate and bicarbonate. The bedrock ground water is characterized by the same anions but is dominated by calcium among the cations. The bedrock ground water also contains higher potassium concentrations than the shallow ground water, indicating poor connection between the two ground-water systems.

2. Metal concentrations are similar to background conditions except for elevated nickel, selenium and strontium.

   Nickel concentrations were only elevated in the shallow ground water and are actually rather low; the average concentration of about 0.2 mg/l is equal to the irrigation standard (there is no drinking water standard).

   Selenium concentrations appear to be attenuated away from the center of the SWMU, indicating that residual materials at the SWMU may be leaching selenium from the soils. The maximum selenium concentrations are consistent with levels found to be naturally occuring in the Golden area by Moran (1976).

   Strontium was found at concentrations equivalent to those found at SWMUs 103, 106, and 107 in both shallow and bedrock ground water. Therefore, because the shallow and bedrock ground-water systems are not believed to be connected, the strontium concentrations are considered to result from the geochemical environment rather than environmental contamination.

4. Radionuclide concentrations are generally equivalent to background concentrations except for the uranium isotopes. The sum of the uranium isotope concentrations is approximately 36 pCi/l in shallow ground water (identical to concentrations found at SWMUs 103, 106, and 107) and is lower in the bedrock ground water. Because the isotopic

ratios indicate the uranium is probably of natural origin. Since there is no record of uranium, contaminated wastes stored at these sites and no uranium above background levels was detected in soils samples from these sites, it is hypothesized that acidic spills at the SWMUs may have leached natural uranium from the soils.

5. Volatile organic compounds are at extremely high concentrations in the close proximity of the SWMU but decrease to non-detectable concentrations within a relatively short distance (on the order of 300 feet). This rapid reduction in concentrations is in good agreement with the results of the soil gas surveys. Because these constituents are relatively mobile in ground water and would be expected to be rather widespread, it is concluded that the gravel lenses that might allow rapid migration of the compounds are discontinuous. This conclusion is supported by the steepening of the hydraulic gradient downgradient of well 4-87.

   In addition, volatile compounds were non-detectable in the most-shallow permeable zone in the bedrock, indicating a poor connection between the shallow and bedrock flow systems and a lack of bedrock ground-water contamination.

In summary, it is concluded that most of the chemical differences result from natural environmental conditions, rather than contamination from the SWMU. However, it appears that naturally-occurring nickel, selenium, and uranium may be mobilized from the soils by residual materials associated with the SWMU and that volatile organics are present in the ground water, almost assuredly resulting from activities associated with the SWMU. Based on relatively low volatile organic concentrations in soil samples, it is possible that the organics are trapped in a discontinuous gravel lense and are not currently being leached from the soil. It is nearly certain that a pool of separate phase solvents is not present at the bedrock interface or in fractured bedrock, again based on the results of chemical analyses of soils obtained from the area of highest ground-water contamination.

5.4.2.3 SWMU 119.2

SWMU 119.2 is located on very thin, clayey colluvial materials. Details of the stratigraphy are shown in cross sections G and H. The colluvium is unsaturated in the vicinity of the SWMU, although incident precipitation may infiltrate the area and then move as perched slugs on top of the low permeability claystone bedrock.

Three wells were installed in the colluvium at and downslope of the SWMU to investigate chemical conditions. Two of the wells (44-87 and 63-86) have always been dry. A third shallow ground-water well (50-87) was sampled for volatile organics (there was insufficient recharge to the well for additional analyses) but none of the volatiles were detected.

Chemical conditions in bedrock ground water at the SWMU have been investigated by sampling well 45-87BR for volatile organics (there was insufficient recharge to the well for additional analyses). Chloroform was detected at a concentration of 18 ug/l in the sample. Because chloroform is not routinely detected in areas of volatile organic contamination and because the concentration is relatively low, the determination is suspected to be laboratory contamination and will be confirmed as additional samples are collected at that well.

Chemical conditions in bedrock ground water were also investigated by sampling well 62-86BR. Samples from this well indicate that the bedrock ground water has relatively low TDS concentrations (about 300 mg/l) and detectable concentrations of both selenium and strontium (about 0.05 and 0.4 mg/l, respectively). Nickel was not detected in the samples. All of the radionuclides were within the background range of values and volatile organics were not detected.

In conclusion, there is very little ground water in the colluvium in the vicinity of SWMU 119.2. The shallow ground water does not contain volatile organics. Bedrock ground water also does not contain volatile organics but does contain low concentrations of selenium and strontium. It is concluded that SWMU 119.2 is not contaminating ground water.

5.4.2.4 Woman Creek Alluvium

The valley fill alluvium in Woman Creek is a thin and sparingly saturated strip of highly permeable sand and gravel. Ground-water flow velocities are quite high when there is a source of recharge, i.e., during infiltration events such as runoff or rapid snowmelt. Between recharge events, water stored in the alluvium flows down-drainage on top of the low permeability bedrock and is consumed by evapotranspiration. Recharge from contiguous colluvial deposits is insufficient to maintain saturation. Hydrographs showing saturated thickness in the alluvium are presented as Figures 5-1 through 5-6.

Chemical conditions in the valley fill alluvium have been investigated by installation of wells both upgradient and downgradient of the 881 Hillside Area (wells 68-86 and 64-86, respectively). The alluvial ground water near 68-86 is characterized by major ion chemistry and TDS concentrations similar to plant background, while both major ion chemistry and TDS are elevated in samples from 64-86 (TDS of approximately 500 mg/l). Samples from both of the wells contain detectable strontium concentrations of about 0.5 mg/l in samples from 64-86 (downstream well) and about 0.2 mg/l in samples from 68-86. Selenium was not detected in samples from either well. Nickel was detected in one of the two samples from well 64-86 but was never detected in samples from well 68-86. Radionuclide concentrations are within plant background ranges in samples from both wells and volatile organics were not detected.

In conclusion, these chemical data indicate a minor degradation of ground water quality in the downstream direction in the valley fill alluvium. However, the degradation takes the form of slightly elevated TDS (near the drinking water standard of 500 mg/l) and detectable concentrations of strontium. Neither of these conditions pose a hazard to the public health or the environment and may result from discharges of colluvial ground water with naturally different chemistry from ground water in the Rocky Flats Allluvium west of the plant.

5.5 CONCLUSIONS

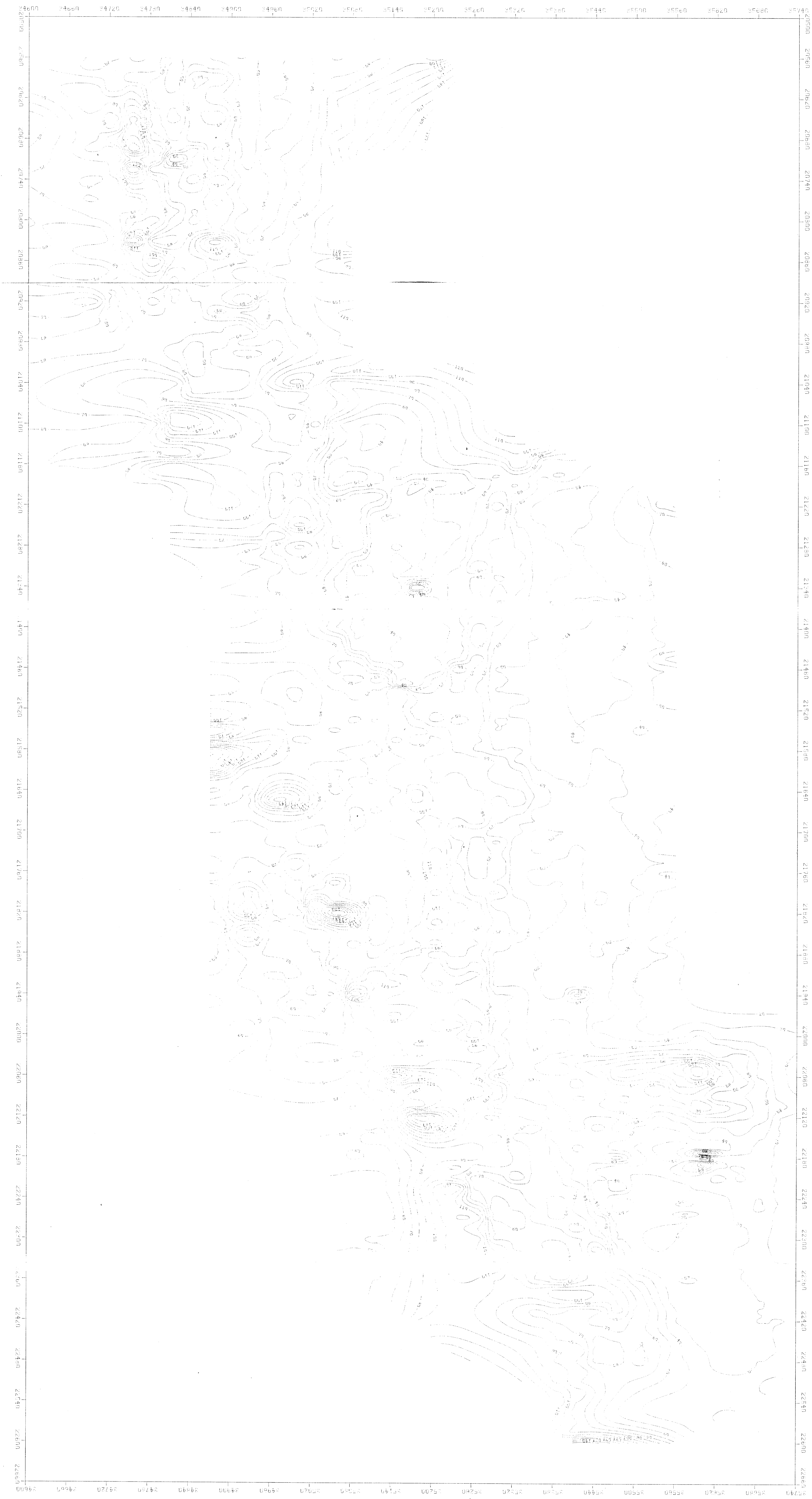
The major conclusion of this remedial investigation of ground-water conditions at the 881 Hillside Area is that there is ground-water quality degradation in the vicinity of SWMUs 103, 106, and 107 (south of Building 881) and at SWMU 119.1. The most significant ground-water quality degradation takes the form of volatile organic contamination. The organic contamination is not areally extensive because of discontinuous stratigraphy and small quantities of ground water, and the contamination does not extend to the Woman Creek Alluvium or into permeable horizons in the bedrock.

In addition, there appear to be elevated concentrations of nickel, selenium, strontium, uranium and major ions; however, all of these elevated concentrations may result from natural geochemical variability with the possible exception of selenium, nickel, and uranium at SWMU 119.1. The non-organic constituents are at levels below or only slightly above applicable standards.

The other SWMU sites at the 881 Hillside Area are not contaminating ground water.

6.000+1

RØCKY FLATS 881 HILLSIDE - EM 31 DATA



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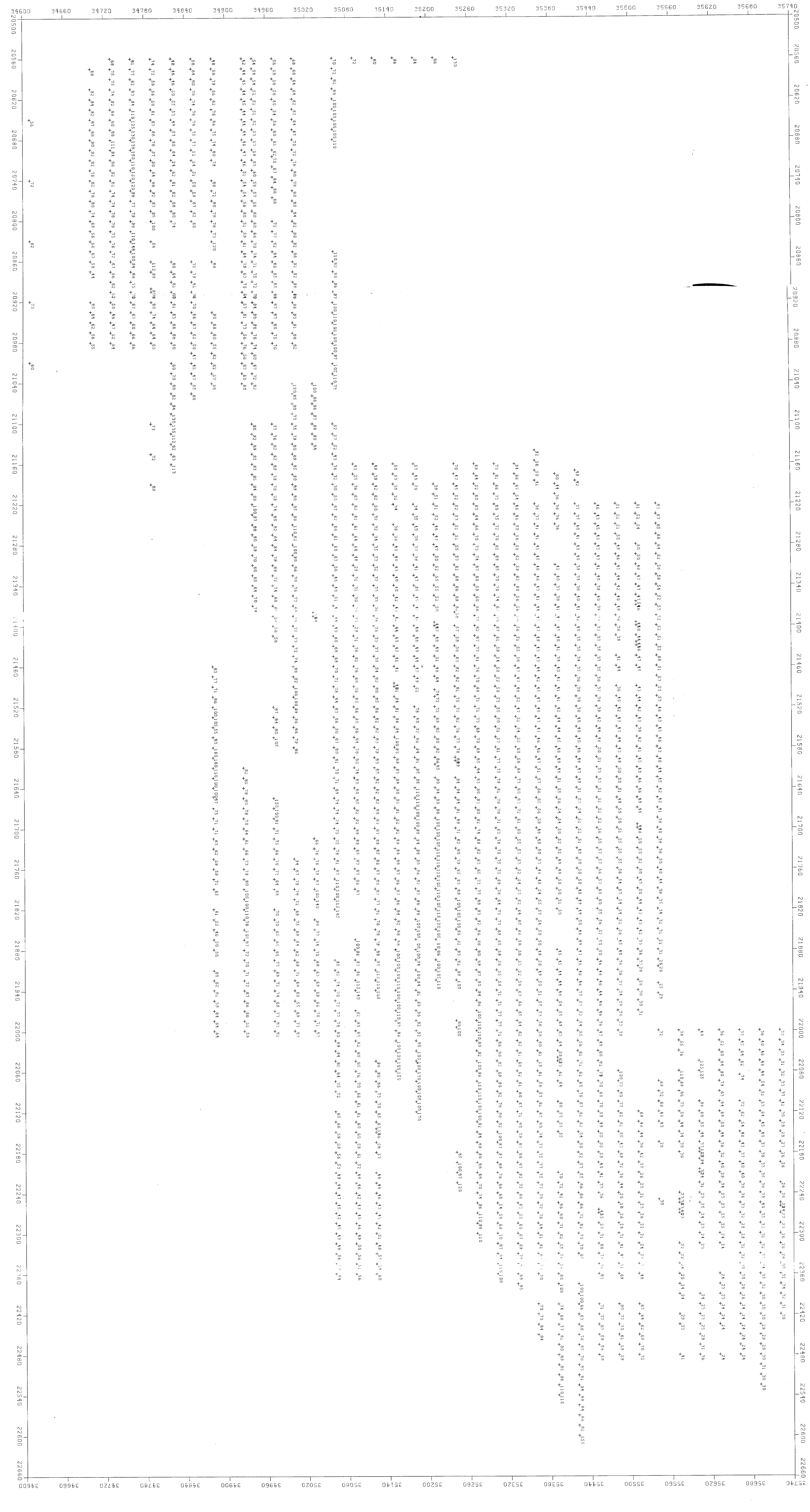
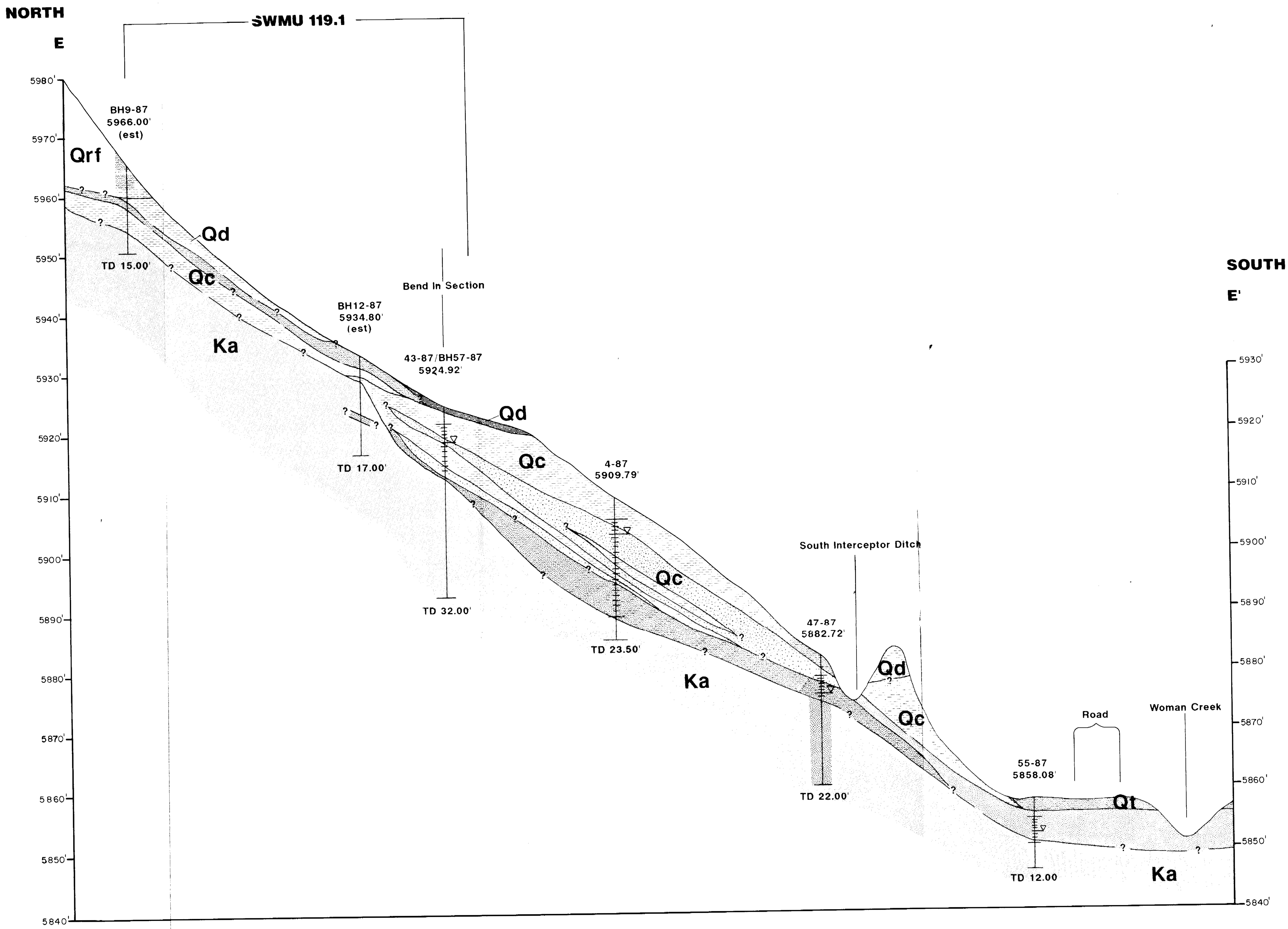
ROCKY FLATS 881 HILLSIDE - EM 31 DATA (PART TWO)





EXPLANATION

QUATERNARY

- Qt — Terrace
- Qd — Disturbed Ground
- Qc — Colluvium
- Qrf — Rocky Flats Alluvium
- Qal — Alluvium

CRETACEOUS

- Ka — Arapahoe Formation (Claystone)
- Kass — Arapahoe Formation (Sandstone)

- Clay
- Clayey Sand or Sandy Clay
- Cobbles and/or Gravel
- Sand and/or Sandstone
- Sand and Gravel
- Silt or Siltstone
- Claystone

2-87/BH3-87 — Well/Borehole Identification
5930.56' — Ground Surface Elevation (Surveyed)

Water Level (Measured 2/4/88)
Geologic Contact (Querried where inferred. Dashed where approximately located.)
Screened Interval

TD 16.00' — Total Depth Drilled

10'
1"=10'
0
50'
Scale: 1"=50'

Vertical Exaggeration = 5x

NOTE: Geology inferred between data points. see plate 4-1 for cross section locations.

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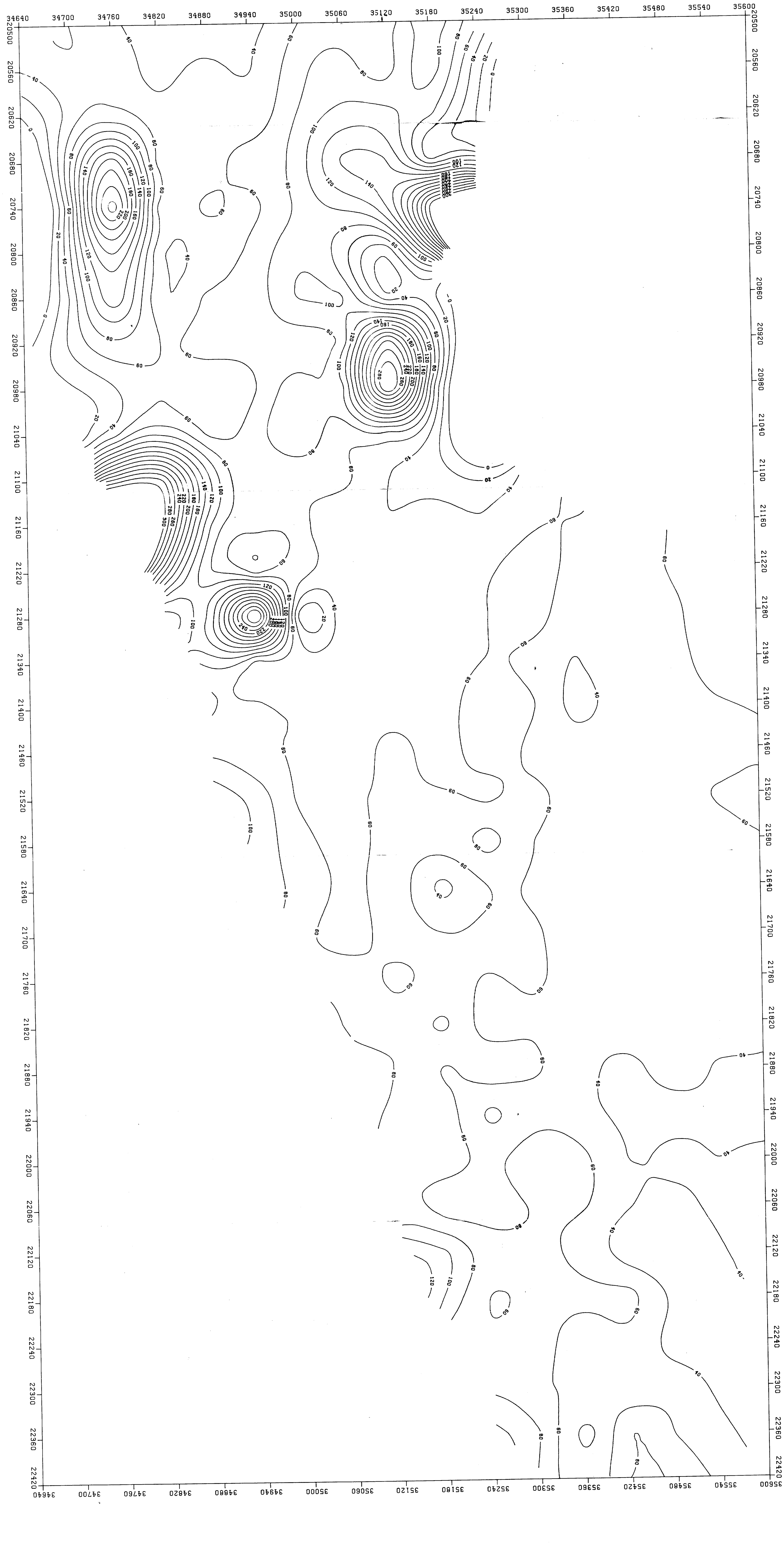
ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado

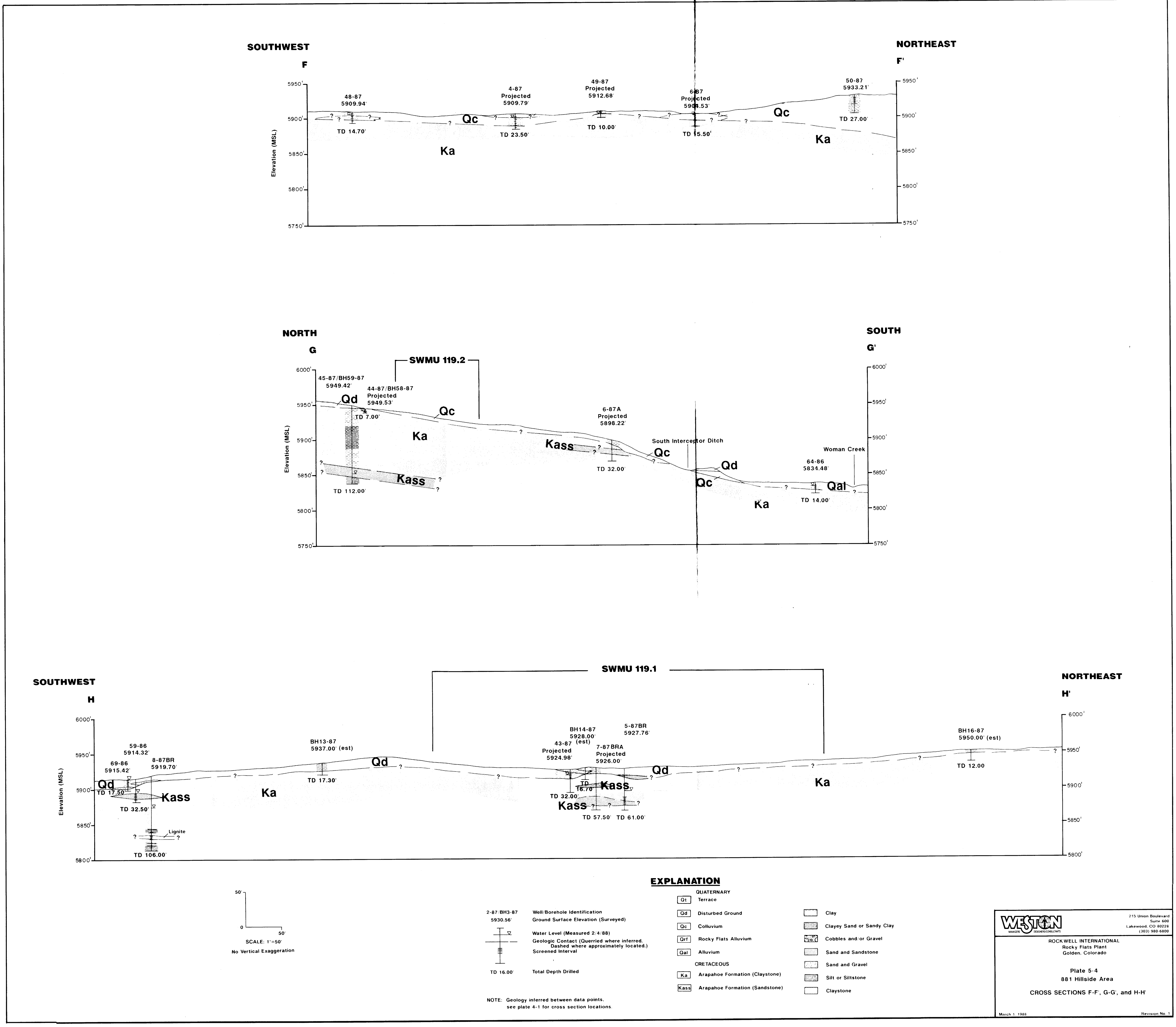
Plate 5-3
881 Hillside Area
CROSS SECTION E - E'
(with Vertical Exaggeration = 5x)

March 1, 1988

Revision No. 1

6.000+1 ROCKY FLATS 881 HILLSIDE - EM34 VERTICAL DIPOLE (4/14/87)





SOUTHWEST
F
NORTHEAST
F'
Elevation (MSL)
5950'
5900'
5850'
5800'
5750'
48-87
5909.94'
TD 14.70'
4-87
Projected
5909.79'
TD 23.50'
49-87
Projected
5912.68'
TD 10.00'
6-87
Projected
5904.53'
TD 15.50'
50-87
5933.21'
TD 27.00'
Qc
Ka
NORTH
G
SOUTH
G'
SWMU 119.2
6000'
45-87/BH59-87
5949.42'
44-87/BH58-87
Projected
5949.53'
TD 7.00'
TD 112.00'
Qd
Qc
Ka
Kass
6-87A
Projected
5898.22'
TD 32.00'
South Interceptor Ditch
Woman Creek
64-86
5834.48'
TD 14.00'
Qal
SWMU 119.1
SOUTHWEST
H
NORTHEAST
H'
69-86
5915.42'
TD 17.50
59-86
5914.32'
8-87BR
5919.70'
TD 32.50'
Lignite
TD 106.00'
BH13-87
5937.00' (est)
TD 17.30'
43-87
Projected
5924.98'
BH14-87
5928.00' (est)
7-87BRA
Projected
5926.00'
5-87BR
5927.76'
TD 32.00'
TD 16.70'
TD 57.50'
TD 61.00'
BH16-87
5950.00' (est)
TD 12.00
EXPLANATION
QUATERNARY
Qt Terrace
Qd Disturbed Ground
Qc Colluvium
Qrf Rocky Flats Alluvium
Qal Alluvium
CRETACEOUS
Ka Arapahoe Formation (Claystone)
Kass Arapahoe Formation (Sandstone)
Clay
Clayey Sand or Sandy Clay
Cobbles and/or Gravel
Sand and Sandstone
Sand and Gravel
Silt or Siltstone
Claystone
2-87/BH3-87 Well/Borehole Identification
5930.56' Ground Surface Elevation (Surveyed)
Water Level (Measured 2/4/88)
Geologic Contact (Querried where inferred. Dashed where approximately located.)
Screened Interval
TD 16.00' Total Depth Drilled
NOTE: Geology inferred between data points, see plate 4-1 for cross section locations.
SCALE: 1"=50'
No Vertical Exaggeration
WESTON
215 Union Boulevard
Suite 600
Lakewood, CO 80228
(303) 980-6800
ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado
Plate 5-4
881 Hillside Area
CROSS SECTIONS F-F', G-G', and H-H'
March 1, 1988
Revision No. 1


EXPLANATION
Qaf Artificial Fill
Qpg Pavement or Gravel
Qd Disturbed Ground
Qal Recent Valley Fill
Qc Colluvium
Qt Terrace Alluvium
Qrf Rocky Flats Alluvium
Ka Arapahoe Formation, Claystone
N
Scale: 1"=100
0 100 200
Contour Interval = 2'
WESTON
MANAGERS DESIGNERS/CONSULTANTS
215 Union Boulevard
Suite 600
Lakewood, CO 80228
(303) 980-6800
ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado
Plate 5-1
881 Hillside Area
GEOLOGIC MAP
March 1, 1988
Revision No. 1

EXPLANATION

Qaf Artificial Fill
Qpg Pavement or Gravel
Qd Disturbed Ground
Qal Recent Valley Fill
Qc Colluvium
Qt Terrace Alluvium
Qrf Rocky Flats Alluvium
Ka Arapahoe Formation, Claystone

N

Scale: 1"=100
0 100 200
Contour Interval = 2'

WESTON
MANAGERS DESIGNERS/CONSULTANTS

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Golden, Colorado

Plate 5-1
881 Hillside Area
GEOLOGIC MAP

March 1, 1988

Revision No. 1